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FOREST SERVICE

WATERSHED MANAGEMENT PROBLEMS
and
RESEARCH NEEDS
in the
NORTHERN REGION

Paul E. Packer, Forester

Intermountain Forest and Range Experiment Station
U. S. Forest Service

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WATERSHED MANAGEMENT PROBLEMS AND RESEARCH NEEDS IN THE NORTHERN REGION

P. E. Packer, Forester

INTRODUCTION

The Northern Region of the Forest Service straddles the Continental Divide from which two great river systems - the Columbia and Missouri - originate. In its far-reaching effects throughout these immense drainages water is probably the most important natural resource. The forest and range lands in the headwaters furnish most of the streamflow of these two rivers. About one-fourth of the combined total streamflow of both drainages is produced on watersheds of the Northern Region. Good management of these watershed lands to insure desirable conditions of streamflow and to protect the soil mantle is an element of ever-increasing importance in the development of the Columbia and Missouri River Basins. Industrial and agricultural developments, highly dependent upon water and power from these streams, are expanding rapidly. Perpetuation of the economic level towards which these developments are headed is problematical, however, without solutions for a number of management problems affecting the production of usable, sediment-free water and the conservation of soil on mountain watersheds.

This paper presents an analysis of watershed management problems and research needs in the Northern, or Region One, territory. It defines the field of watershed management and research functionally within this area. It presents known facts about the hydrologic behavior of watershed lands and indicates the problems for which research must yet provide answers. Those problems still needing research are evaluated with respect to priority and a program of research within the capabilities of the project is proposed.

WATERSHED MANAGEMENT AND RESEARCH OBJECTIVES AND SCOPE

The objective of watershed management is the production of water, usually as streamflow, in the amount and quality desired at a time when it is needed. We try to accomplish this in the following ways: (1) By maintaining the conditions on watersheds that presently provide satisfactory control of water flow and erosion, (2) by repairing and restoring damaged watersheds to conditions that ~~y~~ exert satisfactory control, and (3) by improving the water-yielding characteristics and erosion conditions of watersheds by treatment of land and vegetation. Here, then, we will consider watershed management to mean the management of timber, forage, and other resources in a drainage basi for one or more of the following effects:

1. Control of water quality
2, Reduction of flood discharges
3. Maximum amount of water yield
4. Timing of water yield to meet water needs

Sediment decreases water quality. It also aggravates flood discharges. Loss of soil reduces the capacity of land to absorb and store water and hence, to regulate the amount and timing of water yield. Prerequisite, then, to each of these objectives is a stable soil mantle.

There is a tendency on the part of some to confuse these specific objectives in watershed management with the over-all land management or multiple use objective--that of achieving maximum use of all of the resources in a drainage basin. As defined here, the goals of watershed management are usually compatible with those of forest management, range management, and other resource uses by virtue of the fact that all require stable soil. Beyond this, however, there can be real divergence in watershed management and multiple use management goals. This divergence lies in the fact that the conditions needed to produce desired streamflow are not necessarily those that are required for producing maximum yields of timber, or forage, or wildlife. For example, the need for high-quality water and reduction of flood peaks as desired watershed management goals may require curtailment, or even elimination on some areas, of timber cutting. On the other hand, where greater yield of water is a watershed management goal, the amount of growing stock needed for maximum timber yield may need to be reduced; or species inferior for timber, but which do not use as much water, may be required. Such decisions can be determined only by weighing the relative importance of specific needs in specific localities.

The job of watershed management research is to furnish understanding of the processes that control the quality, amount, and timing of runoff; and to prescribe the land management practices needed to make use of these processes for every intent of watershed management. This means to learn how to maintain, restore, and improve the watershed conditions needed for production of desired runoff under many different circumstances. The variable effects of topography, geology, and climate on the quality and amount of water yield is one kind of circumstance. The requirements for and methods of harvesting timber and forage create still different circumstances affecting water quality and rate of delivery. Other kinds of land treatment such as road building and mining and use of fire, are capable of exerting pronounced and highly variable effects on water. Research needs to learn where we can do something and what we can do to ameliorate the water problems that arise from man's use of these resources. But research also needs to learn what to do and how much can be done to manage land for water alone, irrespective of timber, forage, or other resource uses.

THE WATER SITUATION IN THE COLUMBIA AND MISSOURI BASINS

1. Amount of Water

a. Columbia River Basin:

The Columbia River Basin covers an area of about 166 million acres and discharges a total average annual runoff of about 180 million acre feet. About 41 million acre feet or nearly one-fourth of the total is derived from one-fifth of the land or nearly 35 million acres within Region I (50).

b. Missouri River Basin:

The Missouri River Basin covers an area of 339 million acres or just about twice the area of the Columbia. Average annual runoff at the mouth is about 59 million acre feet. The Region I portion, covering about 82.2 million acres, or 24 percent of the Basin, furnishes about 17 million acre feet, or 29 percent of the runoff (50).

2. Water Developments and Costs:

a. Columbia River Basin:

The Columbia Basin is endowed with great potentialities. Second only to the Mississippi in volume of flow and with a much steeper gradient, the Columbia River can produce power in abundance. Much land needs only the development of irrigation distribution systems to become productive for farming.

Presently there are about 4 million acres under irrigation. Comprehensive plans include irrigation of 3.8 million additional acres and supplemental water for 1.5 million acres now irrigated (80).

Installed hydroelectric power capacity is about 2.9 million kilowatts or 15 percent of the nation's developed capacity. Potentially, the Columbia River is one of the greatest power-producing streams in the world. Existing plans, if carried out, would create approximately 13.1 million kilowatts installed capacity. The potential capacity is estimated at nearly 34 million kilowatts or 40 percent of the nation's total estimated potential (75).

Existing storage capacity of irrigation, power, and flood control structures on the Columbia River is about 9.5 million acre feet. These structures plus those under construction, authorized, and recommended would provide about 27 million acre feet of storage. Of this amount over 9 million acre feet would exist within Region I alone. The potential developable storage capacity of the river is about 100 million acre feet (78).

The total invested value of irrigation, power, and flood control developments in the Columbia Basin today is approximately 2 billion dollars. Installation of authorized and recommended developments would bring this investment to about 7.6 billion dollars, of which 1.9 billion would be in dams (79).

b. Missouri River Basin:

The potential for the Missouri River lies in its development for irrigation agriculture more than anything else. Currently, there are about 5 million acres under irrigation. Proposed plans include about

2.5 million more acres plus supplemental water to a quarter of a million acres now irrigated. Irrigable land in the Missouri if fully developed, is estimated at nearly 13 million acres (81).

Installed power capacity is only about .6 million kilowatts. Authorized and approved developments would increase this to 2.8 million kilowatts. The potential for development--nearly 8.6 million kilowatts--is still only about one-fourth of the Columbia's potential (59).

Live storage capacity of existing reservoirs on the Missouri is over 16 million acre feet. This storage plus that under construction will provide nearly 49 million acre feet (75).

Invested value of the irrigation, power, and flood control facilities in the Missouri River Basin today is about 1.9 billion dollars, Completion of projects under construction plus those authorized and recommended would raise this investment to nearly 8.5 billion dollars of which 1.8 billion would be in dams (59).

Thus, the total value of water handling facilities in the Columbia and Missouri Basins that are dependent in large measure upon clean, usable water from the forest and range lands of Region I is about 3.9 billion dollars. Developments which could eventually increase this value to over 14 billion dollars have already been proposed.

3. Water Problems

Of primary and recurring concern to the people of the Columbia and Missouri River Basins have been the problems of:

1. Snowmelt flood damage, especially along the main stems.
2. Sediment deposition in stream channels, reservoirs, municipal water supplies, irrigation facilities, farm lands, and urban developments, especially in the Missouri.

3. Shortages of late summer water supplies for irrigation.
4. Shortages of winter water supplies for power generation, especially in the Columbia.
5. Local flash flood damage from high-intensity summer rainstorms, more prevalent in the Missouri.

Snowmelt floods, often aggravated by heavy rains, have occurred periodically on the Columbia, more frequently on the Missouri. Average annual flood damage on the Columbia has been in the neighborhood of 26 million dollars (78). On the Missouri it has averaged nearly 148 million dollars (81). Although a wide variety of conditions can cause major floods in both drainages, rapid snowmelt in combination with heavy rainfall is the major cause. In the plains region of the Missouri basin snowmelt or rain on frozen soil have also created flood conditions.

The Columbia River carries a sediment load estimated at about 19 million tons annually. This is substantially less than the 200 million tons estimated for the Missouri, but still enough to create serious damage to downstream water-handling structures. About three-fourths of the sediment movement in these streams occurs during snowmelt runoff periods.

Some sections of both Basins have suffered periodic and substantial crop damage because of insufficient water for irrigation in late summer. This situation has been most prevalent in the Missouri Basin. Low winter flows have resulted in "brown-outs" or inadequate power generation, especially with increasing industrial demands in the Columbia Basin.

The major problems of floods and water shortages occur because the supply is poorly distributed. Sometimes there's too much; sometimes too little. Both problems can be alleviated to a great deal. If all the streamflow were somehow distributed uniformly throughout the year, floods, irrigation deficiencies, and power shortages would not exist. The obvious answer is large storage dams to regulate streamflow. Those projects proposed for the Columbia and Missouri Rivers should pretty well provide the solution for these problems insofar as downstream interests are concerned.

Despite this, there are two problems that storage and streamflow regulation through big dams will not handle. One of these is continuing sedimentation with its attendant depletion of storage and its high maintenance costs. The other is the fact that large dams will not prevent flood discharges nor water shortages above them in the upper watersheds where sizeable investments exist in both rural and urban developments. To prevent or reduce flood damage in these upstream sections, and to protect the life of downstream structures and the billions of dollars in industrial and agricultural reliance placed upon them, every effort is needed to regulate the quality, quantity, and timing of streamflow from upstream watershed lands. More specifically, this means to: (1) reduce erosion, (2) depress snowmelt flood peaks, (3) prevent local "flash" floods, and (4) increase the amount of late summer streamflow. Depending upon specific needs in specific places, these are the major watershed management objectives in Region I.

PHYSICAL CHARACTERISTICS OF REGION I WATERSHED LANDS

From a hydrologic standpoint the precipitation, runoff, soil, and vegetative characteristics on the Columbia and Missouri sides of the Region are vastly different. There are many facts and aspects about these characteristics of which little is known. Review of the things we do know, however, will assist us in more closely pinpointing watershed management problems and the areas where they are important.

1. Precipitation

About 70 percent of the land area in the Columbia River portion of Region I receives more than 20 inches of precipitation annually. Forty percent receives more than 30 inches and 4 percent receives more than 60 inches (82).

On the Columbia side of the Continental Divide there are two different types of precipitation climate separated by the Bitterroot-Coeur D'Alene-Selkirk mountain crest. Westerly winds drop much of their moisture in crossing this barrier, resulting in greater precipitation at comparable elevations on the west side than on the east. Heaviest rainfall in the section east of these mountains comes during April, May, and June. These, also, are generally the months of heaviest snowmelt runoff. Summer rainstorms of moderately high intensity occur but generally not as frequently as on the Missouri side.

By comparison, about 70 percent of the land in the Missouri portion of the Region receives less than 15 inches of precipitation annually. Only about 1 percent receives more than 20 inches (82).

The most significant climatic feature of the Missouri portion of the Region is the great degree of variation in precipitation from year to year, especially in the plains section of eastern Montana. Here, well over half of the annual precipitation of 10 to 15 inches comes as rain during the early summer and most of the remainder as winter snow. Summer precipitation is mostly of the thunderstorm type with high rainfall intensities. Much of this precipitation is lost by rapid runoff which carries with it considerable sediment. In the higher mountains and valleys of the western part of the Basin, most of the annual precipitation of 15 inches or more occurs as winter snow (82).

2. Runoff

The average annual runoff from nearly 35 million acres in the Columbia River portion of the Region is about 14 inches (50). This represents about 41 million acre feet of streamflow. Of this amount about 27 million acre feet or 66 percent originate on 17.8 million acres within exterior National Forest boundaries. The main streams, as well as tributaries, have steep gradients. Tributaries are numerous, but generally short, and drain rather small areas individually. Greatest runoff occurs from snowmelt in April, May, and June.

In the Missouri River portion of the Region a little more than 82 million acres yield an average of about 2.5 inches of runoff (50). This amounts to about 17 million acre feet of streamflow. Of this, about 6.2 million acre feet or 36 percent originate on 10.1 million acres within exterior National Forest boundaries. With the exception of small headwater tributaries with steep gradients, the Missouri River flow is quite different from that of the Columbia. Many tributaries are large and long and their flow, like that of the main Missouri, is slow and sluggish. Snowmelt on the eastern Montana plains generally causes some rise in streamflow in April. A much greater rise is characteristic in June when snowmelt occurs on the higher plateaus and mountains in the western part of the drainage.

Depending upon the manner in which they produce runoff, we might say there are three kinds of watershed lands in Region I.

1. The arid lands, which ordinarily contribute little but surface runoff to streamflow. Generally these lands produce less than 1 inch of runoff annually. About 46 percent of the Region or 54 million acres of land are arid. Ninety-eight percent of the arid lands lie on the Missouri side, stretching across eastern Montana.
2. The sub-humid or semi-arid lands produce some runoff as seepage flow, usually from snowmelt in the spring, but contribute only surface runoff during the remainder of the year. In general, these lands produce less than about 10 inches and more than 1 inch of runoff annually. About 36 percent of the Region or 42 million acres are sub-humid. Sixty percent of these lands lie on the Missouri side, mainly in southwestern Montana. On the Columbia side most of the sub-humid lands are on the western fringe of the Region, in the upper Clarks Fork drainage, and between the Flathead River and Selkirk Range.
3. The humid lands contribute nearly all of their runoff as seepage flow throughout the year. Generally these lands produce upward of about 10 inches of runoff annually. About 18 percent of the Region or 21 million acres are humid. Eighty-two percent of these lands are on the Columbia side, mainly in Idaho and against the Continental Divide, in Montana. On the Missouri side they comprise the higher mountain elevations, principally along the Continental Divide and in southwestern Montana.

With sufficient protective plant cover only a small part of the annual precipitation on all of these lands produces surface runoff. Most of it is disposed of either as seepage flow or to reduce soil moisture deficits. When the protective cover is damaged and the soil is laid bare, however, each of these lands is capable of producing substantial runoff.

3. Soil

There are many kinds of soil in Region I about which very little is specifically known. From a hydrologic standpoint we need more quantitative knowledge about such soil characteristic as infiltration, storage, detachability, and transportability, and about how these characteristics are altered by use. On the basis of their origin and observed reaction under the impact of use, however, the more extensive and important kinds of soil in the Region exhibit some hydrologically pertinent characteristics.

a. The granitic soils, because of their single-grain structure, are non-cohesive and gully easily when once cut by running water. These soils occur most extensively in humid and sub-humid areas, chiefly on the Bitterroot mountain mass or the Idaho batholith and on the Boulder batholith in western Montana.

b. The glacial silts, like the granite soils, tend to be single-grain in structure and are highly erosive once they have been cut by running water. These soils occur in humid, sub-humid, and arid areas, chiefly across the northern part of the Region.

c. The loessal soils are fine-textured and, where deep, have high storage capacity. These soils are erosive when exposed to running water. They occur most extensively in the humid and sub-humid areas in the western part of the Region.

d. The andesitic and rhyolitic soils are somewhat less permeable than the granitic soils but have more coherence and appear less subject to erosion. They occur predominantly in sub-humid areas throughout the mountains of western Montana.

e. The basaltic soils are generally fine-textured, have good storage capacity, and are moderately susceptible to erosion. They occur mostly in the sub-humid areas northwest of Yellowstone Park and near the western edge of the Region.

f. The hard sediment soils from shales and sandstones are silty, sandy, or gravelly loams, moderately permeable and deep, and highly subject to erosion. Several kinds of these soils are found predominantly in the arid plains region of eastern Montana where they have been cut deeply by stream channels. Other phases occur in the sub-humid area along the eastern side of the Lewis and Clark Range on pronounced scarp faces with steep dip slopes. Here the soil is rather shallow but still erosive. The dip and scarp nature of parent rock provides intake areas for seepage flow to underground artesian basins.

g. The soft sediments and terrace soils are poorly consolidated and deep alluvium. They are generally located on benchlands and foothills in arid and sub-humid areas. Two factors make them serious contributors of surface runoff and erosion. One is the sparse cover that often characterizes them. The other is the presence of clay layers with low permeability which restrict percolation of water.

h. The dolomitic soils represent perhaps the most critical soils in the Region from the erosion standpoint. Fine texture and tight subsoil combine to make management of these soils difficult. They erode seriously even where the plant cover is only moderately disturbed. This is particularly true of the red clays. These soils cover extensive areas of the humid and sub-humid lands on the Beaverhead, Gallatin, Deerlodge, Helena, and Lewis and Clark forests.

4. Vegetation

a. Forest:

There are about 37 million acres of land in the Region classed as forest by the Forest Survey. Of this, commercial forest in all ownerships amounts to 27.2 million acres distributed over the Region as follows:

Type	Area			
		Percent of acreage		
	Million acres	N.E. Washington and Idaho	Western Montana	Eastern Montana
Lodgepole pine	6.2	25	35	40
Ponderosa pine	6.0	43	37	20
Douglas-fir	4.9	43	23	34
Larch	4.0	36	64	--
White pine	2.4	88	12	--
Cedar-hemlock-fir	1.4	96	4	--
Spruce	.9	26	44	30
Woodland	1.4	12	4	84
Total	27.2			

Lodgepole pine is of chief importance on humid and sub-humid lands in Montana. Ponderosa pine and Douglas-fir occur mainly on sub-humid areas throughout the Region, but in the Columbia drainage they also occupy considerable areas of humid land. Larch is of greatest importance in western Montana where it occupies humid and some sub-humid areas. Because it occupies much of the white pine mixture in the Inland Empire it is more important there than the Forest Survey figures indicate. White pine and cedar-hemlock-fir are characteristic of humid areas in the Inland Empire. Spruce occurs almost exclusively on humid areas and is most important in Montana, especially the western part.

b. Range:

There are about 60 million acres of non-forest range land in Region I. Fifty-six million acres of this is in Montana. More than half of it is sagebrush-grass and low shrub-shortgrass range in the arid plains of eastern Montana. The portion of this range of direct importance to the Forest Service is some 3 million acres of LU projects.

Of some 15 million acres of publicly-owned non-forest range in the Region, about 2.1 million acres are in National Forests. An additional 5.4 million acres of forested land is also used for livestock grazing.

From a use standpoint only a small part of the 7.5 million acres of National Forest grazed by livestock are of great importance. Of principal concern are about 1.5 million acres of subalpine-grass-forb range, most of which occurs in the humid areas of Montana; about 3 million acres of sedge-pinegrass-bunchgrass range scattered throughout ponderosa pine-Douglas-fir forest in the sub-humid areas of the Region; and about 2 million acres of sagebrush-grass range lying mainly in sub-humid areas of Montana and the western fringe of the Region.

WATERSHED MANAGEMENT PROBLEMS

There are two major kinds of watershed management problems in Region I depending upon the relationship of streamflow characteristics to water needs. The first of these, and probably the most pressing, are the problems of watershed protection. These problems are concerned with two important objectives--maintaining watersheds in protective conditions under continued

continued forest and range use and restoring protective conditions to damaged watersheds. The second--no less important but perhaps not quite so pressing--are the problems of improving water-yielding characteristics of watersheds having protective conditions. These problems relate to increasing the amount of streamflow and altering its timing to meet consumptive demands.

1. Watershed Protection Problems

The main objectives in watershed protection are to hold down undesirable high water flows as much as possible and to control water quality. This requires stable soil mantles on watershed slopes and stable stream channels. The hydrologic conditions needed to do this are few in number but important in their effects.

Conditions needed to hold down high water flows are:

(1) High infiltration capacities

(2) High permeability of soil and substratum

(3) High storage capacity in the soil mantle, especially at the beginning of snowmelt or the start of a rainstorm

(4) Unimpaired channel capacities free of sediment

(5) Slow snowmelt rates

(6) Surface storage of water

Conditions needed for controlling water quality are:

(1) Protective cover on the soil surface

(2) Anchoring of soil by binding with roots and other organic material

(3) Low surface runoff

(4) Well-sodded or rocky channel banks for prevention of scour

(5) Shaded streams to hold down water temperature

All of these conditions are prerequisite for effective watershed protection because they are needed to prevent or minimize quick runoff of snowmelt and rainstorm water which, if not controlled, erodes watershed slopes, scours stream banks and beds, clogs channels, and deposits sediment in downstream water-handling installations.

Compared with many other parts of the country the hydrologic condition of Region I watershed lands for protective purposes is generally good. In recent years substantial improvements in forest and range practices are leaving watersheds in better condition than formerly. Greatest improvements have been in the field of fire control. Wildfire burned area in the Region has decreased from an annual average of 18,167 acres during 1940-44 to 4,087 acres in the 1950-54 period (83). In the past few years timber harvest has doubled from an annual cut of about .9 billion to 1.8 billion feet. Annual cut on National Forests of the Region has increased from about .5 billion to nearly 1.0 billion feet (84). This increase in cutting, with its attendant road building, is extending use to new types on steeper land, shallower soil, and areas of greater water yield. Access roads are generally being built to higher standards with increasing attention given to matters of drainage, crowding of streams, and other items of precautionary nature. Grazing use has resulted in local range deterioration in some places but has not led to the widespread depletion encountered in some other Regions. Substantial progress has been made in livestock reductions and grazing closures on damaged National Forest ranges. Much of this adjustment was accomplished during the 1930-45 period (85). In recent years a shift from sheep to cattle and redistribution of use has alleviated grazing pressures in a number of problem areas, particularly on high elevation summer ranges.

Despite over-all improvements in land use practices watershed protection in Region I still suffers from lack of attention to effective operational measures for control of surface runoff and soil erosion. Many questions continue to arise concerning the impact effects of land use on water and soil. Although problems frequently are created by lack of funds with which to do adequate planning and supervision, perhaps the greatest shortcoming has been failure to record and translate the fund of watershed protection knowledge that has developed throughout the Region into useful management guides. The result has been that in numerous instances protection measures learned from experience in one place have not become available for application elsewhere. There is great need Regionwide to gather and classify this knowledge into working guides for protection purposes. This job will require effort in at least two directions. One of these is careful examination and appraisal of the effects of past and of current practices on such observable processes as erosion and sedimentation. Criteria for prescribing a number of needed protection measures can be established by this approach. The other involves research to develop management measures where effects of treatment are not readily apparent nor susceptible of evaluation except by methods of careful quantitative measurement.

a. Maintenance Problems

(1) On Forest Lands

The 1955 Annual cut of timber in Region I was 970 million board feet from National Forests and about 830 million feet from state and private lands. This timber harvest involved logging activity on about 112,000 acres of which approximately 62,000 were national forest. Ninety-five percent of the timber harvested came from Columbia River Basin watersheds. The total cut from all lands involved building of approximately 1600 miles of truck and jammer roads and 1000 miles of tractor roads. This amount of road is equivalent to an area of about 10,000 acres from which all protective plant cover is annually removed. The volume of merchantable sawtimber in Region I is about 136 billion board feet (86). It is estimated that this volume will sustain an annual allowable cut of about 2.7 billion feet of timber. This amount is approximately 50 percent more than is currently being cut. Much of the increased harvest needed to attain allowable cut levels will be realized from the virtually untapped 6.2 million acres of lodgepole pine forest, much of which occurs in the Missouri River headwaters. A shift from spruce salvage to larch and Douglas-fir will also accelerate cutting in these latter two types. With present methods of logging-tractor and jammer--the amount of soil disturbance from logging and road building can be expected to increase correspondingly. Such increase might well result in logging of as much as 160,000 new acres and baring of soil on as much as 15,000 acres of new roads each year. Current logging and road building activity, not to mention probable future increases, present some specifically important watershed maintenance problems on forest land. Because most timber harvest activity has been and will continue to be in the Columbia Basin, these problems are most important there.

(a) What are the requirements for access and logging road layout--location, design, construction--to prevent or reduce soil movement into stream channels.

Observational evidence on many logging areas in all Regions, as well as that from scattered instances of record, indicate that the large bulk of soil reaching stream channels comes from roads and skid trails. Chief offenders are roads and skidtrails that disrupt or infringe upon natural drainage channels. Almost as bad, if not equally so, are those with steep gradients over which surface runoff can move at high velocities.

Love and Benedict (52) measured sediment yields from two adjacent forested watersheds on the Boise National Forest in Idaho. One of these had been logged some six years previously; the other was unlogged. Sediment from the logged drainage was from 10 to 40 times greater than from the unlogged one. Most of the active sediment source area in the logged watershed consisted of roads and skid trails. Rose (87) has shown that the sediment loads from these drainages were more closely related to surface runoff than to total runoff. Preliminary information from a current study (88) in the Boise Basin Experimental Forest in Southern Idaho indicates that roads which either cross drainage bottoms or parallel the stream channel in close proximity are the greatest sediment producers.

Hoo~~o~~ver (37) has shown that steep logging roads on one of the Cowetta watersheds increased sediment in the stream to 87 times that from an unlogged watershed. Weitzman and Trimble (99) demonstrated the advantage and practicability of keeping roads in the rough terrain of West Virginia to grades of less than 10 percent as a means of holding down sediment.

There are two basic logging layouts in use in Region I--tractor and jammer. Each of these systems has its own road characteristics. The average square mile of tractor-logged forest in Region I requires about 5 miles of truck-hauling roads, much of it climbing, and 16.7 miles of tractor roads, some of which may be very steep. These roads occupy about 10 percent of the area. Jammer logging roads, on the other hand, are nearly always on contour with the exception of an occasional ascending road. An average square mile of jammer-logged forest requires about 13.3 miles of truck road occupying approximately 8 percent of the area. Because tractor roads can be built on very steep grades, they constitute a potentially greater sedimentation threat than do most jammer road layouts. Roffler (65) made an observational study of a large area of jammer logging in the white pine type of northern Idaho. He reported the only evidence of sediment was from culverts that had failed.

Road surfaces, bared of all protective plant cover and compacted by heavy equipment, afford a ready source for accelerated runoff and sediment unless provisions are made to disperse water from them. Some idea of the impairment in water-absorbing capacity of roads is furnished by Boe (89). He found that the infiltration capacity on tractor skid roads in 180-year-old lodgepole pine forest in Montana was only 5 percent of that on undisturbed areas two years after logging. Results from similar studies (90) in mature larch-fir forest in Montana show the infiltration capacity on tractor roads to be only 4.1 percent of that on undisturbed areas. Four years after logging it was still only 3.5 percent.

From a practical standpoint it is probably quite certain that we aren't going to prevent all erosion from logging. Immediately following logging there is bound to be some movement of loose soil from fills, cuts, and road surfaces. Important, however, is whether eroded material becomes sediment in stream channels and, if so, how much and for how long. Tripp and Trimble (77) report active sediment production from eroding roads on 20-to-35-year-old logging areas in Montana lodgepole pine. Similar instances can be found in all of the forest types of the Region.

Results from these and other similar studies almost universally support impressions gained from observation concerning the effects of improper road locations, steep grades, and poor road drainage facilities on sediment production. Most of the sedimentation problems experienced today as a result of logging roads are much more a matter of failure to adequately employ control measures than of not knowing what these measures are. Almost without exception failure to apply known protection measures arises from two sources:

1. inadequate training of road construction and maintenance personnel in the care needed to avoid unnecessarily creating sediment-source areas, and
2. a desire to cut or cheapen road or logging costs.

Solution for the first of these lies in more attention and emphasis to education of supervisory and woods personnel. Just how much we can cut road and logging layout costs and still buy needed watershed protection in the form of sediment control, however, is a problem requiring physical and economic evaluation. Watersheds vary in kind and value of timber, in quantity and uses of water, and in resistance to erosion. The amount of money that can be spent justifiably to protect them, therefore, also varies.

We know enough now about most of the physical measures needed to do a creditable job of sediment control if we but apply that knowledge on the ground. Meanwhile, in Region I, we need to learn, both physically and economically, what costs in road and logging system layout provide the greatest returns in the form of sediment control under different conditions of water quantity, forest type, soil, and topography. To learn this, evaluation studies should be initiated on demonstration watersheds to compare the sediment production characteristics and economics of sediment control as a cost of logging from the best tractor, jammer, and, perhaps, Skyline Crane logging layouts we can possibly install. Of greatest importance in this respect are the following forest land areas.

Runoff zone	Forest type	Soil type	Forest type	Soil type
Humid	white pine	glacial silt loess granitic	lodgepole pine	dolomitic andesitic
	larch	glacial silt		
	spruce-fir	granitic		
sub-humid	ponderosa pine	granitic	Douglas-fir	dolomitic
	Douglas-fir	glacial silt		hard sediments

(b) What are the requirements for corrective measures needed to provide proper drainage from road and trail surfaces.

So far we have-considered only the preventive aspects of road layout--location, design, and construction--on sediment production. Road maintenance, including corrective post-logging measures, are equally important, for it is on them that we must rely mainly for runoff and erosion control on the areas of unavoidable disturbance attending logging. During the past ten or fifteen years a program of corrective measures aimed at runoff and erosion control has been instituted following logging on most national forest timber sale areas. This program has varied considerably with time and place insofar as the kind of measures and their intensity of application are concerned. In general they have included such treatments as construction of cross-ditches on roads to divert water, building water bars on skid trails to prevent accumulations of water there, piling slash in skid trails to reduce the velocity of running water, and reseeding to improve infiltration and soil stability conditions. In numerous instances these measures have not proven adequate for controlling runoff and stabilizing soil. One of the reasons for failures has been lack of knowledge concerning design and installation specifications for cross-ditches and water bars that would prevent erosive concentrations of rainstorm and snowmelt water on road and skid trail surfaces. Another has been a general reluctance on the part of timber managers to use grass species for revegetation of disturbed surfaces because it is thought that it impairs natural regeneration of timber.

The U. S. Forest Service Road Handbook gives maximum spacings between cross drains at different road gradients. They vary from spacing of 800 feet at a grade of 5 percent to 300 feet at 10 percent. In numerous instances these standards have been followed in the absence of better ones. Another standard for cross-ditch spacing that has had wide usage is the formula 1,000/percent grade-spacing in feet. Obviously, the erosive characteristics of soils are too variable for either of these two rule-of-thumb standards to be applied universally. Numerous instances have been encountered in Region I where continued rilling and gullying on surfaces of ditched roads reflects the inadequacy of treatment. Guides for spacing of cross-ditch and water bar drains on roads and skid trails need to be developed on the basis of soil erodibility, amount and intensity of rainfall or snowmelt runoff, and the inherent ability of natural vegetation or litter accumulation to stabilize surfaces quickly.

Much of the basic information needed to develop such guides is readily available. It is to be found in a record of effects of post-logging erosion control work on roads and skid trail surfaces from past sales. Careful examination of a number of logging areas in each forest and soil type of the Region is needed to record this information in a systematic manner. Research's responsibility in this is assistance in establishing criteria and methods for collecting data, analysis of records to develop guides, and evaluation of these guides on new logging operations. Need for developing road drainage guides is greatest in the following forest areas:

Runoff zone	Columbia Basin		Missouri Basin	
	Forest type	Soil type	Forest type	Soil type
Humid	white pine	glacial silt loess granitic	lodgepole pine	dolomitic andesitic
	larch	glacial silt granitic		
Subhumid	ponderosa pine	granitic	Douglas-fir	dolomitic
	Douglas-fir	glacial silt		hard sediments

(c) What are the effects of pattern and amount of timber removal on peak discharge and quality of spring runoff.

In the Northern Region a variety of weather conditions contributes to the character of spring runoff from snow-packed forest watersheds. Two-thirds to three-fourths of the total volume of streamflow occurs during the spring runoff period--usually April through June. There is little specific data available, however, on which to establish definite relationships between runoff characteristics and the conditions that control them. Some idea of the relationship of seasonal precipitation to runoff has been obtained from 18 years of streamflow records on Benton Creek, a 900-acre white pine forested watershed on the Priest River Experimental Forest in northern Idaho (70). These records show that for each inch of winter season precipitation (November through March) 0.95 inch appear as streamflow, for each inch of spring-fall precipitation (April through June and October) 0.65 inch is yielded as streamflow, and for each inch of summer precipitation (July through September) only 0.08 inch results in streamflow. These records clearly point up the position of winter precipitation as the major source of streamflow from watersheds of the Region.

In historic times four major floods have occurred on the Columbia River: in 1948, 1894, 1896, and 1849. Much information is available for the 1948 flood, much less for the 1894 flood, and very little for the other two. Results of survey studies (91) (23) made during the 1948 flood indicate that four principal meteorological conditions combine to produce spring runoff floods from Northern Region watersheds:

1. Water equivalent of snow cover above normal
2. Lower than normal air temperatures during April or May or both months
3. Sustained above-normal air temperatures covering the watersheds during late May and June
4. Above-average precipitation during the period of greatest melt in May and June.

All of these conditions were present in 1948 when cold weather in April and most of May retarded snowmelt even at lower forest elevations, followed by warm weather at all elevations in late May and June accompanied by rain. Comparable circumstances prevailed in 1894. Similar spring flood discharges also affect various tributaries of the Columbia and of the Missouri River much more frequently without creating major flood conditions on the main stems. Notorious in this respect are the Kootenai and Clearwater Rivers, and, to lesser extent, the Sun River.

In the Columbia River portion of Region 1 the forests even at low elevations are in relatively deep snow country. Fall rains after mid-September partially, and sometimes completely, recharge the soil mantle. Almost without exception the soil mantle is at or above field capacity shortly after spring snowmelt begins. When unusually warm weather occurs at lower elevations and is accompanied by rain, snowmelt is rapid resulting in a quick and large increase of subsurface seepage flow. With the soil mantle saturated, continued melting and rain causes some subsurface seepage to bleed out rapidly and contribute to surface runoff. These discharges quickly produce high streamflow peaks on small and intermediate size drainages. Surface wash from bared roads and slopes, as well as streambed and bank scour by high discharges, are capable of moving large amounts of sediment into transit in these streams.

This situation, most pronounced in the white pine, larch, and spruce forests of northern Idaho and western Montana, presents the problem of how to manage these forests for minimum quick subsurface flow of water to streams. An obvious aspect of the problem is the importance of preventing as much direct surface runoff as possible by employing logging methods that leave stable soil surfaces and provide adequate drainage of water from roads and other bared surfaces. There are two ways by which water absorbed by the soil can be prevented from flowing quickly to streams. One is by retaining it within the soil by maintaining high retention storage space in the mantle. The other is by making it percolate deep into underlying strats, thus converting potential surface flow into ground-water flow.

Water in retention storage can be removed from the soil mantle only by evapo-transpiration processes. The greater these processes, the larger the retention storage opportunity in the soil mantle. Any control of quick subsurface flow, therefore, can be expected to occur under a forest cover that provides the most evapo-transpirational loss during the growing season. The depth and texture of the soil, however, impose some limitations to the effectiveness of forests in this respect. Shallow, sandy soils, such as the granitic soils on steep slopes, hold relatively little water in retention at field capacity. These soils dry rather completely whether forested or not. Soils of greater depth and finer texture, such as glacial silts, soft sediments, and loess, contain more water susceptible to evapo-transpirational loss and, thus, provide greater opportunity for forest to exercise its influence on subsurface flow.

On slopes, water draining through soil moves downward and laterally, so that its course tends to parallel the slope (17). Wherever trees occupy the soil, decaying litter incorporates below the surface and roots penetrate the soil, creating a micro-structure that favors downward water movement. Although tree roots can en~~c~~large cracks in parent rock, it seems unlikely that they have much significant influence over gross geologic conditions and the movement of water below the soil mantle. Where soil is underlaid with rock that offers little chance for downward movement of water, therefore, quick subsurface flow cannot be expected to be reduced much even under good forest cover. The influence of forest on subsurface flow appears to be pretty much confined to the soil mantle and to its ability to improve the retention storage and permeability of the soil. Even with the best of these conditions, the circumstances of kind of weather, depth and texture of soil, and character of parent rock may not prevent development of high subsurface flows in streams (42).

Depending upon their age, vigor, tolerance, seeding characteristics, and susceptibility to disease and insects, the forests of northern Idaho and western Montana are harvested by one of two general methods--clearcutting in blocks or partial cutting.

In the white pine region approximately 1.1 million acres of the better sites have been reserved as blister rust control units. With a few exceptions, management of mature and overmature white pine timber in these units involves clear cutting in rather large blocks up to several hundred acres in size, followed by burning of slash and, finally, planting (92). It is felt that these larger blocks are more desirable than small ones from the standpoint of controlling dissemination of blister rust spores. On the other hand, outside of control units forest management will eventually have to be directed towards growing of other species such as grand fir, Douglas-fir, cedar, and hemlock. These species are tolerant and can probably be managed suitably by partial cutting methods.

In larch forests it appears that much of the timber will be harvested in clear-cut blocks of up to about 60 acres in size. Larch, particularly the older stands, does not respond well to partial cutting and, in fact, tends to deteriorate with such treatment (64). Where clear cuts are made, natural reproduction from surrounding trees can be obtained adequately over the areas cut if they are not appreciably larger than 60 acres in size and the ground is well scarified.

Although spruce forests can be reproduced and managed on some deep soil areas by partial cutting, the shallow-rooted characteristic of spruce and its consequent tendency to wind-throw when partially cut indicate that, for the most part, spruce will probably continue to be harvested by block clear-cutting methods rather than partial cuts.

The clear-cutting treatment used in each of these forest types means that the interception and shading effects of the forest cover will be negligible for a period of 10 to 20 years following timber harvest. Unpublished data from interception studies in white pine forest on the Priest River Experimental Forest in northern Idaho (93) indicate that the soil mantle and substratum in these cleared areas may have to handle as much as 8 inches more water from snow alone than where a full forest canopy exists. With some additional water from rainfall during the fall and spring the total additional amount to be disposed of might easily be as much as 10 inches each year. This additional amount of water together with probably sharp reductions in transpirational draft caused by removal of timber means more water available for streamflow. Added to a soil mantle already overtaxed during spring periods of rapid snowmelt and rain, this additional water may well aggravate flood discharges and cause increased sediment through ripping of streambanks. This situation raises the question of how much of the land should be so bared at any one given time to avoid such an effect becoming damaging from a flood peak and water quality standpoint. Most important forest areas in this respect are the following:

Runoff zone	Columbia Basin	
	Forest type	Soil type
Humid	white pine	glacial silt loess hard sediments granitic
	larch-fir spruce	glacial silt hard sediments granitic

Where the species to be managed are tolerant and partial cuttings can be used advantageously, there appears to be more leeway for controlling the size and pattern of openings in the forest canopy and, hence, the amount and location of additional water reaching the ground than is possible where clear-cutting is employed. Under these conditions the questions arise as to what intensities and patterns of partial cutting provide the most control over snowmelt rates and of how such cuttings affect peak streamflow and sediment production. Forest areas most important in this respect are the following:

Runoff zone	Columbia Basin	
	Forest type	Soil type
Humid	grand fir, Douglas-fir	glacial silt loess
	cedar, hemlock	hard sediment

(d) What are the effects of controlled burning and dozer piling of slash as silvicultural operations on peak, timing, and quality of streamflow.

In land management the effective use of fire as a tool requires two fundamental things: knowledge of fire effects and knowledge of fire behavior. Reactions of many foresters to prescribed use of fire is one of reluctance to employ it. Reasons for this are:

1. Fear and distrust as a result of experience with violent wildfire.
2. Fear of inability to control prescribed fires effectively. Some prescribed burns

have resulted in unhappy experiences with wildfire.

3. Lack of knowledge about what fire can accomplish when properly used.
4. Fear of possible adverse effects which are not yet fully understood. Effect on soil and water is one of these.

Present knowledge of fire effects and behavior in wildland management is far from complete, but it is generally recognized that burning has a useful place in many situations.

Under natural conditions nearly all of the major forest types of the Northern Region are dependent on fire for their perpetuation. Ponderosa pine, Douglas-fir, white pine, larch, and lodgepole pine are all seral types, perpetuated largely by wildfire. The role played by fire in regeneration of these forests is principally that of opening up the forest and creating a mineral soil seedbed. Where these forests are protected from wildfire but are opened up by cutting, controlled fire is used as a convenient way of obtaining a mineral soil seedbed. An additional reason for its use is also to reduce the wildfire hazard by controlled burning of logging slash.

The hydrologic consequences of fire have received research attention in many~~pas~~ parts of the country. For the most part, however, research has not provided much information on the quantitative effects of fire upon such characteristics as infiltration rates, peak discharges, and sediment production nor of the length of time over which these effects prevail. From the studies of fire that have been made it is apparent that uncontrolled wildfires that burn the forest floor clean can have highly harmful effects on infiltration and storage characteristics of the soil mantle, especially where reburns occur within a few years (33) (34) (2). Floods and sediment from resulting high surface runoff and erosion rates can reach devastating proportions (20) (48) (94). On the other hand, the immediate hydrological effects from controlled burning in connection with silvicultural operations rarely assume such spectacular proportions. Not so apparent, but of perhaps greater importance, are the long-lasting and cumulative hydrologic effects of controlled burning, expecially since the management of nearly all Northern Region forest types is predicated on fire use and many thousands of acres are subjected to its impact annually.

In general, surface runoff and erosion from hillsides have been observed to be accelerated for only a few years by fire. For entire watersheds, however, this does not seem to be true. Accelerated erosion effects lasting 8 to 10 years have been observed following fire in southern California mountains (94). Anderson and Trobitz (3) have shown that recovery of plant cover to maximum density and their containment of peak discharge rates may require up to 40 years. Rowe (66) has demonstrated the effects of periodic burning in the Sierra Nevada foothills. He concludes that burning at intervals progressively reduces the infiltration capacity of the soil. Rowe and Colman (67) have shown that water yield from shallow soils appears little affected by burning. In deeper soils removal of deep-rooted vegetation by fire increased the total amount of water yield. There is considerable doubt that useable water yield was benefited much because most of the increase appeared as high storm flows of surface runoff charged with sediment.

Numerous instances can be cited to illustrate the increase in surface runoff and erosion from fire. This has been established qualitatively in many places and requires little further evidence for support. The significant aspect of fire's effect upon hydrologic processes involves quantitative evaluation. The conditions under which damaging hydrological effect are severe or inconsequential need to be established. Some soils, especially the heavier textured ones are more susceptible to altered infiltration characteristics and hence, surface runoff and erosion. Some forests produce dense plant growth quickly after fires. In others vegetative response is slow and sparse.

In some parts of the Region slash piling with a dozer is becoming a common practice. Numerous instances occur where not only the heavier slash but also the finer organic material as well as some soil is scraped off the surface leaving the ground bare and subject to the erosive impact of rain and runoff. Though such complete removal of logging debris is considered harmful, the practice still continues. To what extent this method of disposing of slash affects runoff, and hence, peak flow and sediment, is not known.

Considering the importance of holding down flood peaks and sediment and the large forest operating area in which prescribed burning and dozer piling are used each year in the Columbia drainage portion of the Region, it is important to evaluate the effects of these two activities there on peak discharge and sediment yield. In the Missouri portion of the Region, where water supply is frequently inadequate, where a rather large portion of irrigation water comes from direct stream diversions, and where greatly accelerated timber harvest is developing in forest types for which prescribed burning is commonly employed, it appears important to assess the effects of controlled fire and dozer piling on timing of flow and sediment production rates. The following forest land areas appear to be of greatest importance in these respects:

Runoff zone	Columbia Basin		Missouri Basin	
	Forest type	Soil type	Forest type	Soil type
Humid	white pine	loess glacial silt granitic	lodgepole pine	dolomitic andesitic
	larch-fir	glacial silt granitic		
Subhumid	ponderosa pine	glacial silt	Douglas-fir	dolomitic
	Douglas-fir	granitic		hard sediments

(2) On Range Lands

There are four major kinds of range in Region I, each with considerable variation in plant composition and cover condition.

Most extensive is the sagebrush-grass and low shrub-shortgrass range covering about 47 million acres of arid plains in the eastern part of the Region. Some portions of this range, extending into badland areas, have probably always had high geologic sediment production rates. A far larger portion, however, is contributing sediment to the Missouri River system at highly accelerated rates. Periodic drought, less than 15 inches annual precipitation, high intensity summer rainstorms, and sparse plant cover in many places as a result of overgrazing and fire, have made this range the heaviest sediment producer in the upper Missouri Basin. Sediment measurements (95) from September 1929 to November 1930 disclosed that 32,414,000 tons of sediment had been discharged at the mouth of the Yellowstone River. During the same period the Big Horn River discharged 16,516,100 tons. For the Big Horn River drainage this amounts to an annual sedimentation rate of 667 tons per square mile. Approximately 12,520,000 tons or 76 percent of the discharge occurred during high intensity rainstorms in the months of June, July, and August.

Approximately 1.5 million acres of subalpine-grass-forb range occupies higher elevation watersheds of the Region. About 70 percent of this range occurs in the headwaters of the Missouri Basin. This range is used extensively for summer livestock grazing and also furnishes summer forage for a large number of elk. Past overgrazing, especially from sheep use but in local areas also from elk, has deteriorated protective plant cover on parts of this range to the point where it is no longer effective in controlling water from high-intensity summer rainstorms that occur each year. As a result portions of the range have developed gully systems which probably foster rapid bleeding out of subsurface seepage from snowmelt, thus aggravating peak streamflow in the spring and reducing the subsurface flow available for later summer streamflow. Some tributary streams arising on this range carry a substantial load of sediment during high runoff stages--a product of gully erosion and streambank and bed scour.

The dense timber type, consisting mainly of lodgepole pine with a sparse understory of inferior forage, occupies about 6 million acres. Relatively unimportant as livestock range because of sparse forage, this type is grazed to some extent by big game and used by them more for shelter. From a range standpoint this type offers no particular watershed problem.

Open ponderosa pine-bunchgrass range occupies about 3 million acres scattered throughout the Region in subhumid areas. Understory vegetation furnishes an important source of livestock forage, especially for cattle. This type also furnishes a large part of winter range use by deer and elk. In some areas, especially along the western fringe of the Region and in the upper Clark Fork and Kootenai drainages, overgrazing has occurred. Native bunchgrasses have been replaced by a sparse cover of annual weeds, accompanied by increased surface runoff and erosion.

In 1955, the National Forest ranges in the Region provided 689,461 animal unit months of actual livestock use on about 6.3 million acres distributed as follows (96):

Portion of Region	Animal Months' Use	Percent of Regional Use	Area Used (Million acres)
Montana	559,922	81	4.7
Idaho	77,403	11	1.2
Washington	29,729	5	.3
South Dakota	22,407	3	.1
Region I	689,461	100	6.3

The fact that 81 percent of actual grazing use occurs on

Montana ranges emphasizes the importance of range watershed problems in the upper Missouri Basin.

Present conditions on some of these ranges indicate that, despite continued grazing use, there is need for arrestive action. A 1949 estimate (13) of range conditions on National Forests of the Region indicated that 56 percent of the rangeland was in satisfactory condition, 30 percent was fair, and 14 percent was considered poor. More recent estimates indicate an even higher proportion of poor condition. Adjustments have been made or are under way in some of the more obvious instances of range damage. On numerous areas, however, signs of range deterioration are often not recognized, even by some of those most closely in contact with the evidence. There is need for better recognition of range condition and trend on areas which are not obviously depleted. Required for this is more specific knowledge of plant cover and soil conditions that effectively cope with high-intensity rainfall and of how these conditions are affected by grazing use. Need for watershed maintenance criteria of this sort is greatest on the Missouri Basin ranges.

(a) What are the plant cover and soil conditions required to prevent accelerated surface runoff and soil erosion during high-intensity summer rainstorms.

Flash floods from accelerated summer storm runoff have become a rather commonplace occurrence on many western range areas. Numerous studies have been made confirming the conclusion that this condition is the result of misuse of the range, chiefly by overgrazing and fire (19) (26) (5) (7). Not only has this been shown to be true on western ranges but it has also been effectively demonstrated on eastern pastures and woodlots subjected to livestock use (1) (44) (11). There is little, if any, need for more demonstration of the bad hydrologic consequences of overgrazing and the benefits of good range management. Needed instead is specific quantitative knowledge concerning the plant cover and soil conditions required for containment of surface runoff and erosion; the ecological potential and, hence, probability of achieving such conditions; and the effects of chemical amendments to the soil for improving plant cover on range areas having inherently adverse growing conditions.

Some start has been made towards developing range watershed protection criteria based upon amount and condition of plant cover. Studies on spring-fall bunchgrass and cheatgrass range on granitic soils in Idaho have revealed two cover characteristics to be the dominant ones controlling amount of surface runoff and erosion (61). These are ground cover - the percent of soil surface covered by plant basal area and litter - and the size of bare soil openings between plants and litter patches. It was concluded from this study that, on ungrazed grassland ranges such as these, a ground cover of at least 70 percent and bare openings of less than 4 inches across between plants and litter patches provide about as much control of surface runoff and soil movement as can be expected. Similarly, studies on the subalpine-herbaceous range on heavy limestone soils in central Utah (97) and on herbaceous range on intermediate weight soils from gneiss in northern Utah (56) show that a 70- to 75 percent ground cover is needed for effective control of storm runoff and erosion. Thus, protective cover requirements apparently are not very different on any of these three widely separated and geologically different areas. Applicability of these criteria on still different soils in Region 1 requires testing by making comparative checks with infiltrometer equipment. Range areas in greatest need of such tests are as follows:

Runoff zone	Columbia Basin		Missouri Basin	
	Range type	Soil type	Range type	Soil type
Humid			subalpine-grass-forb	dolomitic andesitic
Subhumid	sagebrush-grass	soft sediments	sagebrush-grass	soft sediments
Arid			low shrub-shortgrass	hard sediments glacial silts

(b) To what extent and by what methods of management can Ranges in Region 1 be grazed and still maintain protective conditions for summer storm runoff and erosion control.

There are three main physical processes involved in grazing use that contribute to range depletion and loss of control over summer storm runoff and erosion. These are (1) reduction in surface area covered with litter due to the downhill sloughing action of trampling on slopes, (2) compaction of soil from the weight of animals, especially on gentle topography and heavy soils, and (3) reduction in the litter-production potential by repeated removal of excessive amounts of herbage as forage. Effective watershed management still continues to be handicapped by a lack of information about tolerable limits of trampling disturbance and forage utilization.

Some information on the storm flow and erosion behavior of local sites under the impact of several different degrees of simulated trampling is available from one study on bunchgrass and cheatgrass ranges in southern Idaho (62). The result of this trampling was to increase both surface runoff and erosion from high-intensity rainfall markedly. Of more importance, however, are the management implications involved. This study showed that where bunchgrass and cheatgrass range on granitic soil has less than 70 percent ground cover almost any trampling that disturbs more than 10 percent of the surface area is effective in further reducing the amount of ground cover and increasing the size of bare soil openings. It is highly questionable whether range in this condition can be improved in the face of continued use. Where as much as 20 percent of the following constitute the range areas of greatest need:

Runoff zone	Columbia Basin		Missouri Basin	
	Range type	Soil type	Range type	Soil type
Humid			subalpine-grass-forb	dolomitic andesitic
Subhumid	sagebrush-grass	soft sediments	sagebrush-grass	soft sediments
Arid			low shrub-shortgrass	hard sediments glacial silts

b. Restoration Problems

(1). On Forest Lands

Next in importance to the problems of maintaining protective watershed conditions under continued use are the problems of restoring watersheds that have been damaged. Probably the two most important activities that have contributed to forest watershed damage in Region I have been wildfire and road construction, the latter especially in connection with logging. On some burns, especially where the forest has suffered more than one fire, active erosion still exists after some years, particularly where forest regeneration has not occurred. Active continuation of erosion also exists on some logging areas where operations have been completed for some time. It is quite certain that effective restoration measures need to be applied to those damaged forest lands if soil stabilization is to be achieved within any reasonable length of time.

(a) What vegetational measures are needed for controlling runoff water and stabilizing soil on eroding road surfaces, cuts, and fills.

Beyond the problem of developing proper drainage to reduce road and skid trail erosion is that of stabilizing these surfaces, as well as those of cut and fill slopes, with vegetation. Deep road cuts and long fill slopes, in unstable soils, such as loos granites, glacial silts, and loessal soils are the major trouble spots. In some areas repeated reseeding has failed to establish cover on these sites when they were most greatly in need of it. Reasons for failure appear to be unstable seedbed, lack of moisture near the soil surface, and perhaps lack of fertility in the raw subsoils exposed.

Considerable research has been done on cover establishment of road banks in several parts of the country. Satisfactory methods for establishing such cover have been developed for both humid and semi-arid regions (41) (12) (45) (49). In most places wattling, sod-planting, seeding, or staking is needed to develop satisfactory cover. In combination or singly these procedures have produced good results in stabilizing road banks in many parts of the country, especially on permanent highways.

In humid regions where favorable growing conditions exist, such as the Inland Empire portion of Region I, native vegetation often comes in rapidly to protect road banks. Even there, however, deep cuts and fills that expose large areas of relatively sterile subsoil make plant cover establishment difficult. Under the adverse growing conditions that exist in drier portions of the Region, principally in the ponderosa pine type, methods of obtaining protective plant cover on bare surface have not yet been satisfactorily developed. Needed are studies to develop practicable and economical methods of mulching to provide a stable seedbed and to evaluate the effects of fertilizers in speeding up plant cover development on these critically unstable areas of loose soil. Needed also are studies to determine kinds of plant cover, methods of establishment, and amounts required for soil stability.

Problems of stabilizing soil are more closely associated with soils than forest types. The sedimentary soils covering extensive areas in the west-central part of the Region are exceptionally stable under use. On the other hand, the granitic soils on parts of all the west side forests and the glacial silt soils covering large areas across the northern part of the Region seem much more vulnerable to erosion in the absence of adequate plant cover. Areas for which effective revegetation measures are most urgently needed as follows:

Runoff zone	Columbia Basin		Missouri Basin	
	Forest type	Soil type	Forest type	Soil type
Humid	spruce-fir	glacial silt granitic	spruce-fir	glacial silt dolomitic
	white pine-larch	glacial silt granitic loess		
Subhumid	ponderosa-pine-Douglas-fir	granitic		

(b) What are the comparative effects of restoring timber and of retaining brushland cover in old burns on snowmelt runoff peaks and soil stability.

The scars of forest fires exist throughout the northern Rocky Mountains, especially in the Columbia River tributaries of northern Idaho and western Montana. Results of large forest fires have been described by Lewis and Clark (98). In the 40-year period from 1908-1947 over 12 million acres burned, some of it two or three times (8). New stands of timber have regenerated on some burned areas. On others brush has gained a foothold and it will be many years before they revert to forest through normal successional processes. In some areas--reburns in particular--active erosion is still in progress, aggravated by trampling disturbance from large elk herds which utilize the brush for forage. Improvement of ground cover conditions is needed on these areas to stabilize soil.

From a timber management standpoint a desirable objective on these brush-covered burns is the development of a new forest stand. Presently unproductive, these burns contain some of the best ~~timber~~ timber-producing sites. Planting and seeding, needed on these sites, is complicated by the problem of removing brush competition.

From a game management standpoint, a decision should eventually be made as to what numbers of elk and deer are desirable to maintain within given drainages and the amount of brushland range needed to sustain them. These big game animals, especially elk, rely on browse in the burns during the winter months. The areas of greatest use and upon which these animals rely are the southerly exposures at intermediate and lower elevations. It is, therefore, reasonable to conclude that most browse areas reserved for wintering big game would consist principally of southerly exposures.

From a water standpoint, management objectives in the Columbia River drainage, where the most extensive burns and elk concentrations exist, are to hold down snowmelt runoff peaks and sediment production. Little factual information is available concerning the relative effects of brush cover and timber on these two characteristics. Observations made during the 1948 snowmelt flood on the Columbia River and again during Operation Snowpack in the spring of 1952 indicate that snowmelt in open brushlands on southerly exposures occurred from several days to two weeks ahead of that on comparable forested areas (29). To what extent such advance in the time of brushland snowmelt over that on forest land might be effective in reducing peak streamflow stages by moving water out of low and intermediate areas before the heavy flows arrived from the higher elevations is not known. Consideration of the watershed affects of restoring these burns to timber-producing status and of maintaining some portion in game winter range condition requires investigation of the relation of different brush and timber cover conditions on quantity and timing of streamflow. Of principal importance in this connection are the following forest land areas.

Runoff zone	Columbia Basin		Missouri Basin	
	Forest type	Soil type	Forest type	Soil type
Humid	white pine	loessal granitic hard sediments		

(2). On Range Lands

It has been pointed out that there is need for better recognition of condition and trend on range areas which are in neither very good nor very bad condition. On these ranges native perennial grasses and forbs are generally fairly abundant. Some surface runoff and soil movement may occur during heavy rainstorms, but the topsoil is, for the most part, still intact. The potential exists for natural recovery of many such areas by protecting them from excessive grazing use.

On the other hand it is estimated that there are better than 200,000 acres of native range on the National Forests of Region 1 and from 2 to 3 million acres of range outside the National Forests on which the native perennial plant cover is so depleted that measures beyond mere protection from grazing use are needed to restore them to satisfactory condition. By far the greatest portion or range land needing rehabilitation treatment is abandoned farm land in the plains region of Montana. Other critically depleted areas on which restoration effort is needed occur on the high elevation grass-forb ranges and the lower elevation sagebrush-grass and low shrub-shortgrass ranges.

(a) What artificial revegetation and mechanical measures are needed to restore critically eroding range areas to protective condition.

Although a considerable amount of range revegetation research has been conducted in the Northern Region leading to development of recommendations for revegetating depleted areas in the major range types (28), there are still critically eroding areas where methods have not been developed or have proven inadequate for storm runoff and erosion control. With transfer of range reseeding research responsibility from the Forest Service, revegetation investigations on a modest scale are continuing under the Forage and Range Section, Field Crops Research Branch, Agricultural Research Service.

Methods of revegetating cheatgrass covered abandoned farm lands in the shortgrass plains region to crested wheatgrass have been developed (27). Still needed are methods or rehabilitating thousands of acres of shortgrass range that are rapidly becoming badlands. Also needed is development of methods for improving plant cover conditions on badly eroding subalpine range. Past efforts indicate that soil fertility deficiency is a problem in establishing plant cover on eroded subalpine range sites in Region I (73). Agricultural Research Service is currently conducting reseeding studies on this range in Carrot Basin of the Gallatin National Forest and on Dry Fawn Bench of the Beaverhead Forest to evaluate the effects of nitrogen and phosphorus fertilizer treatments. They are also continuing reseeding investigations on shortgrass and sagebrush-grassland ranges for purposes of forage improvement. Needed is an extension of similar studies to the poorer and more critical sites for purposes of runoff and erosion control.

Virtually no use has been made of mechanical measures such as contour terracing or mulching on range lands in Region I. The effectiveness of contour trenching for catching and storing surface runoff before it can begin to transport soil has been demonstrated in numerous instances (6) (71). The beneficial effects of mulching on establishment of new plant cover have also been repeatedly shown (43) (72) (68). Contour trenching and mulching in combination with reseeding should be attempted on pilot plant scale in some of the more difficult situations where control of surface runoff and soil stabilization has not been achieved by reseeding alone.

Winter game ranges present a real problem in revegetation. Reseeding is complicated by the steepness and difficult accessibility to many areas. Protection from late winter and early spring grazing and trampling is a problem that limits success. The plants best suited for controlling runoff and stabilizing soil are not necessarily those most needed for game feed. Sod-forming grasses are needed for the former. Tall grasses and shrubs such as willow,aspen, serviceberry, and bitterbrush are required for winter forage. Some progress has been made in developing methods of propagating browse, especially bitterbrush, at the California and Intermountain Stations (39) (9). More experimental work is needed, however, to improve thesemethods, extend them to other species, test their applicability for practical use on Region I ranges, and evaluate their effectiveness for maintaining protective watershed conditions. With adequate browse on managed game range, it is quite possible that the ground cover disturbance now experienced on browse-depleted range from pawing for grass would be substantially reduced.

Ranges on which badly depleted areas are most greatly in need of intensive rehabilitation measures are as follows:

Runoff zone	Columbia Basin		Missouri Basin	
	Range type	Soil type	Range type	Soil type
Humid			subalpine-grass-forb	dolomitic andesitic
Subhumid	Sagebrush-grass	soft sediments	sagebrush-grass	soft sediments
	PP-DF-grass	granitic	PP-DF grass	hard sediments dolomitic
Arid			low shrub-shortgrass	hard sediments glacial silt

(b) What are the grazing management methods and techniques required to restore protective watershed conditions to depleted range.

The amount of tramping disturbance and forage utilization that a range watershed can safely absorb without damage to its hydrologic characteristics for runoff and erosion control has been mentioned as a problem for which more quantitative information is needed. Closely allied is the problem of determining to what extent and how damaged range watersheds can be grazed and still be restored to protective condition. Some badly depleted areas, especially on subalpine sheep range, sagebrush-grass winter game range, and the shortgrass range, will in all probability require special revegetation measures and complete protection from grazing during the period of rehabilitation. By far the larger parts of these ranges, even though damaged in some degree, still retain the potential for natural recovery to protective watershed condition provided thay are not further damaged by trampling and excessive forage removal.

Studies in Colorado (25) have shown that on open ponderosa pine-bunchgrass range, moderate grazing use which removed one-third of the herbage resulted in a twofold increase in surface runoff during summer storms without producing any significant increase in the amount of soil eroded. Heavy use that removed nearly two-thirds of the herbage doubled the amount of soil erosion. It has been shown in Idaho (62) on bunchgrass range that, where the ground cover is substantially less than 70 percent, disturbance of even 10 percent of the ground surface by trampling causes substantial further reduction in ground cover, enlarges bare soil openings, and increases surface runoff and soil erosion. This suggests that even light use on this kind of range may be too much.

These and a number of other investigations (76) (19) (26) (5) have shown that heavy grazing use is detrimental to effective control of runoff and soil movement and that protection from grazing can and usually does have a beneficial influence. Little, if any, research has been done, however, to determine what grazing use short of complete protection can be made of damaged ranges while they are recovering.

The only way in which range in unsatisfactory condition can become effective for watershed protection purposes is by improvement of ground cover and soil conditions needed for infiltrating and storing water in the soil mantle. Such improvement can take place only when two conditions are satisfied. The first of these is that the amount of plant material left after grazing use and which becomes ground cover is in excess of the amounts destroyed by trampling and lost by oxidation, runoff, and wind processes. The other is that the amount of improvement in physical characteristics of the soil, such as dispersion of the soil particles in the surface layers into large and porous aggregates and increase in pore-space condition of all layers of the soil profile, exceed the amount of retrogression in these characteristics resulting from trampling compaction and raindrop impact.

Quantitative evaluation of these vegetation and soil relationships, their effects on disposition of water, and the effects of grazing and trampling activity on them is needed to learn in what degree and under what conditions a large part of our range can be grazed so that the trend in recovery to conditions for effective watershed protection will be positive. Solution for this problem is most urgent on the following range areas:

Runoff zone	Columbia Basin		Missouri Basin	
	Range type	Soil type	Range type	Soil type
Humid			subalpine-grass-forb	dolomitic andesitic
Subhumid	sagebrush-grass	soft sediments	sagebrush-grass	soft sediments
	PP-DF-grass	granitic	PP-DF-grass	hard sediments
Arid			low shrub-shortgrass	hard sediments glacial silt

C. Watershed Improvement Problems

Water shortages occur throughout the Missouri River Basin on a general scale in about one year out of ten. These Basin-wide deficiencies occur mainly because of the drying effect created by the Continental Divide on prevailing eastward-moving air masses and because of the seasonal nature of streamflow which discharges about 75 percent of the annual supply of surface water by the middle of July. A planned system of large dams on the main stem of the Missouri and some larger tributaries promises to substantially reduce shortages in the downstream areas by providing storage for these large early-season volumes of streamflow.

Shortages also exist locally in different parts of the Basin almost every year. These local shortages are occasioned by the same conditions that contribute to Basin-wide deficiencies but, in addition, are affected by large variations in winter precipitation. Heavy snowfall may occur in parts of the upper Basin one year while other parts are experiencing below-average precipitation. Also, in the upper Basin the profiles of many streams that feed major tributaries such as the Gallatin, Madison, Beaverhead, and Jefferson Rivers are steep and afford little opportunity for dams with which to provide surface storage of early season streamflow. Much of this early season runoff, consequently is lost downstream as far as these upper Basin valleys are concerned, leaving irrigation dependent upon inadequate summer and fall streamflow, There is need, therefore, not only for increased supplies of water in the Missouri Basin but, even more importantly, for improvement of streamflow timing to meet summer irrigation demands in those areas where adequate surface storage is impossible.

The main objectives in attempting to manage Missouri Basin watersheds for improved water yields are twofold--to increase total annual streamflow, without aggravating spring snowmelt streamflow peaks that already exist and to shift as much of the high stage spring runoff as possible to increased summer season flows. To accomplish these objectives certain hydrologic conditions, in addition to those required for controlling water quality, are needed.

Conditions needed for increasing annual streamflow are:

1. Low interception losses of precipitation.
2. Low evaporative losses from snow, water and soil surfaces.
3. Low transpiration losses by vegetation.

Conditions needed for altering the timing of streamflow area:

1. High surface storage capacity in reservoirs.
2. Deep, highly permeable valley fills for water spreading.
3. Low winter and early spring snowmelt rates.

The best opportunities for creating hydrologic conditions needed to improve water yields in the upper Missouri Basin lie on the high mountain watersheds where a large portion of the annual precipitation occurs as winter snow. Here also are about 2.5 million acres of lodgepole pine forests subject to deep snow pack and on the verge of an accelerated timber harvest program.

That quantity of streamflow is increased by removal of timber has been demonstrated on several occasions in this country and elsewhere in the world (10) (36) (51) (15). The additional water available for streamflow has also been shown to result from lowering of interception and transpiration losses that occur with a tree canopy (101) (100) (47). There is little evidence, so far, to show that removal of timber materially affects the one hydrologic condition subject to vegetative influence that is necessary for shifting the time of streamflow, namely, reduction and delay of snowmelt rates. Nearly all research so far has been concerned with accumulation and disappearance of snow on the ground under various conditions of forest cover. With the exceptions of the classical Wagon Wheel Gap experiment and a year or two of records on the recently cut Fool's Creek watershed at Frazer, Colorado, there are no measurements of the changes in quantities of water yield or of alterations in timing that result from any particular timber cutting. Thus, while it appears that treatment of forest stands can bring about increased water yield, the magnitude of these yields in relation to the forest treatments required to produce them and the extent to which delay in water yield can be shifted by forest treatments are far from being known. These aspects are important because it makes a great deal of difference whether peak discharges are increased in damaging amounts or whether delay in time of yield is in terms of weeks or only days.

(1) On Forest Lands

(a) What are the effects of size of opening, pattern of timber cutting, and amount of timber removed on quantity, peak discharge, timing, and quality of streamflow.

Many studies have shown that virgin forests provide the most complete natural control possible over surface runoff, streamflow peaks, and erosion. In recent years it has become evident that forest lands can be managed so that water yields are greater than those from virgin forests. Due regard must be given to the fact that such management may also produce undesirable consequences insofar as other characteristics of streamflow are concerned.

The earliest study in this country on the influence of forests on snow accumulation and melting was carried on in California in 1912 (16). From it came the conclusion that greatest accumulation and slowest depletion of snowpack occurred in forests having small openings in which the snow surface was shaded by surrounding trees. A study in ponderosa pine forest in southern Idaho (18) indicated essentially the same effect, that the combination of greatest accumulation and slowest depletion was provided by numerous shaded openings in the forest. On the east-side Cascades studies (31) (14) have shown that snow in old-growth timber stands remained on the ground a week longer than in partially cut stands and two weeks longer than on open unshaded cut-over lands. On the open lands 70 percent of the snowpack disappeared in one week in contrast to four weeks of evenly distributed depletion of snow on the heavily timbered areas.

A further study (32) in ponderosa pine forests in Idaho has suggested some timber management implications with respect to snow storage. It has shown that the differences in shading provided by the same kind of cover on north and south aspects were responsible for differences in accumulation during the winter period due to substantially lower melting rates on north exposures where partial topographic shading and more acute angles of solar incidence produced less direct radiation. It was concluded that on north aspects large openings provided the greatest storage and retention of snowpack whereas on south slopes management for numerous small openings shaded by trees was most desirable. Other timber management implications in connection with prolongin snow-water runoff have been suggested by Anderson's (4) empirical analysis of forest cover effects on snow accumulation and melt in red fir stands of the Sierra Nevada Mountains. This analysis indicated that maximum snow accumulation can be obtained by cutting successive narrow strips normal to the direction of maximum solar radiation in such a manner that a "wall and step" forest, with the wall to the south and the steps to the north, is created. It also indicated that depletion of snowpack water equivalent was least in strips with a width equal to half the tree heights, Anderson's analysis regarding quantitative differences in snow water accumulation and melting in forest and in large openings agree closely with findings of Kittredge (47), Mixsell (60), and Wilson (102). Radiation studies (24) at the Willamette Snow Laboratory have shown that snow persists longest in small, shaded clearings, next longest in dense forest, and least in large openings. The reason for this was shown to be the fact that snow in small openings is shielded from direct solar radiation by surrounding trees and loses more long-wave radiant heat to the open sky overhead. In dense forest long-wave re-radiation from overhead tree canopy resulted in faster melting while in large openings all wave radiant heat transfer toward the snow was greatest and produced greatest melting.

In none of these studies was any measurement or evaluation made of actual differences in water yield or timing created by differences in accumulation and melting of snow. To date, the Wagon Wheel Cap study (10) still stands as the only completed investigation in which quantitative evaluation of changes in streamflow characteristics in relation to changes in snow accumulation and melting rates has been made. Results from this investigation showed that on an aspen-covered watershed, previously denuded of a mixed-forest cover by cutting, the average 7-year annual increase in water yield over that from an uncut watershed with a dense, tall, mixed-forest cover was 0.96 inch. Of this increase, 83 percent came off as streamflow during the highflow stages in the spring and produced peak discharges about 50 percent greater and 3 days earlier than those from the uncut watershed. Other than denuding the treated watershed once and allowing aspen regrowth to develop, no attempt was made in the Wagon Wheel Gap study to control the cover conditions that produced the observed streamflow changes.

To evaluate the independent effects of intensity of timber removal on water added to the soil which becomes available for streamflow a study was conducted at Frazer, Colorado, from 1938 to 1944 (101). This study was conducted on 20 five-acre plots in virgin lodgepole pine timber and water yields as streamflow were not measured. Precipitation, snow accumulation, melting, and soil moisture at the end of melting and again in the fall were measured on all plots for two years before any timber cutting. Similar measurements were made for 4 years after removal of timber from 16 of the plots. Snow evaporation was measured only in one large open area and evaporational losses from the plots were estimated on the assumption they varied inversely as the density of timber cover remaining on the plots. This assumption is not necessarily an accurate one and such question still remains concerning the magnitude of evaporational losses from snow surfaces, both on the ground and on forest tree crowns. This study did show that the water which became available in the soil in excess of field capacity and, hence, presumably as streamflow, increased with intensity of cutting. In the most intensive cutting this increase was from 10.3 inches to 13.5 inches or 31 percent. No measurable difference in the length of the snowmelt period under the different conditions of treatment was observed. It was concluded that more rapid melt in the heavier cut stands offset the greater snow accumulation there.

A similar study (30) in young lodgepole pine timber in which about half the trees were removed by thinning cuttings showed essentially similar results. Snow water available for streamflow was increased about 20 percent, presumably due to decreased interception losses, and the rate of spring snowpack depletion was accelerated. No evaporation measurements were made; consequently, how much depletion resulted from melting and how much from evaporation was not determined.

With the exception of one study in Idaho (32) which pointed out differences in snow accumulation due to north and south slope aspects, none of these studies attempted to evaluate the influence of terrain on snow accumulation. Results from five studies (60) (40) conducted at the Upper Columbia and Central Sierra Snow Laboratories, provide preliminary information on the effects of elevation, slope, aspect, and curvature characteristics. They show that for each 100-foot increase in elevation, snow water equivalent increased from 1.2 to 2.5 inches; for each 1 percent decrease in slope, water equivalent increased about 0.5 inch; for each 10-degree deviation of aspect from south water equivalent increased from 0.2 to 1.0 inch; and for concave surfaces from 3.0 to 6.0 inches, more water occurred than on convex surfaces. Further studies are needed to better develop such terrain-snowpack relationships.

Increases in snow accumulation from timber cutting have been concluded by most investigations to occur because of greater evaporation from intercepted snow on forest canopies than from snow falling directly on the ground snowpack. To account for this the rate of evaporation from tree canopies must be much greater than any measured evaporation rates from snowpack. In nearly all studies so far evaporation has either been included with melt as snowpack depletion or has been estimated. Further evaluation of evaporation rates from tree canopies and ground snowpack is needed to more accurately determine how much of the additional water in snow accumulated from timber cutting actually becomes available for streamflow.

Fundamental to hydrology of snow-fed drainages is understanding of snowmelt processes--the methods of heat exchange between snow and its environment, their magnitudes, and methods of determination. Of the four methods of heat exchange--conduction, convection, condensation, and radiation--convection and condensation are generally credited by most litera- as the main sources of heat for snowmelt. Studies (35) (69) (58) at the several western Snow Laboratories in recent years indicate that this is not necessarily true, that the relative importance of these snowmelt factors depends upon a number of conditions--cloudiness, snow albedo, aspect, wind, air temperature, dewpoint, and density of forest cover. Needed are further studies to quantitatively evaluate the effects of the heat sources on snowmelt rates, the conditions under which they operate, and to what extent these conditions are influenced by manipulation of the forest cover. Areas for which more intensive snow management investigations on forest lands are most urgently needed are as follows:

Runoff zone	Columbia Basin Forest type	Columbia Basin Soil type	Missouri Basin Forest type	Missouri Basin Soil type
Humid			lodgepole pine spruce-fir	dolomitic andesitic
Subhumid			Douglas-fir	dolomitic hard sediments

(b) What are the effects of riparian cover removal on quantity, peak discharges, timing, and quality of streamflow.

Very little study has been made of evapo-transpiration losses of water along streams in the mountainous areas of the West. It is known, however, that riparian vegetation exerts a tremendous draft on water during the summer growing season. In one study (21) in northern Utah riparian water losses were found to consume about a third of the total August to October streamflow. Another study (103) in California has indicated such losses may amount to as much as 38 to 46 inches of water from the riparian zone during the summer season. Still another study (38) in California indicates that summer season salvage of water resulting from burning of riparian vegetation was probably more than enough to account for measured increases in summer streamflow. These studies, limited though they are in scope, are enough to suggest that riparian water salvage may offer a good chance to improve summer season streamflow yields.

The streamside zone of many drainage basins in Region I supports dense stands of spruce, alpine fir, lodgepole pine, Douglas-fir, and cottonwood, as well as alder and willow thickets. Capture of riparian water losses by such vegetation is a principle which probably needs no further testing but its application and quantitative evaluation in Region I does. Needed are studies to determine the quantitative effects of riparian cover removal on streamflow quantity and, especially, of its effects on timing of any increased streamflow. Effects of such treatment, especially in close proximity to streambanks, on water quality also requires evaluation. Most important in this respect are the following forest areas:

Runoff zone	Columbia Basin		Missouri Basin	
	Forest type	Soil type	Forest type	Soil type
			Spruce-fir	(All on deep valley fills)
			Lodgepole pine	
			DF-alder	
			cottonwood-willow	

(2) On Range Lands

In view of the importance of snow as a source of water in the Missouri Basin, consideration must also be given to the possibilities for improving water yields from about 1 million acres of high-elevation range that receives heavy snowfall each year. This range has received little attention as a possibility for water yield improvement through snow management.

Considerable evidence is available which indicates that water yield improvement from some range lands may be feasible by converting deep-rooted plant cover to one with a shallow root system (22) (63). Prerequisite to any effort in this direction, however, is the need to maintain an adequate protective cover on the soil and highly permeable soil conditions.

(a) What are the effects of drift fences or planted windrows for accumulating snow, delaying melt, and altering the time of streamflow from snow fields on high-elevation range.

With the exception of one preliminary study in Utah (53) and a current one in Colorado, no research has been done in this country on the effects of snowdrifting on water yields. The Utah study, as well as snowdrifting studies on the Siberian steppes (46), has demonstrated that opportunity probably exists to delay release of water from deeply drifted snowpacks in sufficient quantity and long enough to have an appreciablelowering effect upon peak streamflow and increase later summer flow. In Utah 7-foot slat fences had no measurable effect on drifting but similar 11-foot fences did induce drifting. At the beginning of snowmelt these drifts contained 20 inches more water than nearby undrifted areas. When snow had disappeared from the undrifted areas the drifts still contained 15 inches of water which was released over a 2-week longer period. In Siberia sunflower fences have been shown to drift snow to depths up to three times those obtained on open undrifted areas. Surmach (74) reports that snow melting has been effectively retarded by covering the surface with straw and other mulches.

With the exception of the Snow Laboratory studies little is known of terrain influences on accumulation and melting. The influence of topography in relation to wind on snow accumulation requires quantitative evaluation in order to determine the most efficient kinds of snowdrifting sites. Also needed are further studies to evaluate the efficiency of different barriers for drifting and the effects of the several heat sources that cause melt or ablation rates of induced drifts. Finally, studies to determine the gross watershed effects of induced drifting on quantity and timing of streamflow are necessary.

Most important areas offering opportunity for affecting yields by drifting are as follows:

Runoff zone	Columbia Basin		Missouri Basin	
	Range type	Soil type	Range type	Soil type
Humid			Subalpine-forb-grass	dolomitic andesitic

(b) To what extent can increased water yields be achieved by vegetative conversion from deep-rooted to shallow-rooted plant cover.

Lying below and intermingled with the Douglas-fir forests of the upper Missouri Basin in Montana are about 2 million acres of sagebrush-grassland range. With the exception of local areas used by antelope and by deer for winter forage, the sagebrush on this range is practically worthless. Large areas of this range type are being converted to grassland range by roto-beating, spraying, and burning to eliminate sagebrush. Objective of this action is improved cattle forage. In many instances the native grass cover remaining is being fortified by artificial reseeding.

Removal of deep-rooted sagebrush may offer opportunity for improving water yields, providing any increase in forage production is derived from plants having substantially shallower root systems than does sagebrush. Numerous studies have been made that demonstrate the effects of root depth on transpirational draft. One study (63) in

Arizona has shown that a grass-covered lysimeter effected substantial savings inwater available for streamflow as compared to a brush-covered lysimeter. It was concluded that the main reasons for this difference were, first, that the deeper-rooted brush was effective in drying the soil to deeper levels and second,, that the grasses used water for growth during the summer where most of it would be lost by evaporation anyhow, whereas the brush began to grow earlier in the spring during the period when its use of water coincided with the high water yield period. These results demonstrate an important recent concept, namely, that evapotranspiration during the dry growing season is governed by available soil moisture whereas, during the season of ample soil moisture, rates are controlled by atmospheric factors, chiefly the effects of eddy diffusion and heat energy from solar radiation on vapor pressure gradient (57) (54).

In northern Utah a plot study (22) gave some indications of the magnitude of increase in water made available for streamflow that might be expected through cover conversion. Soil moisture deficits at the end of the growing season on aspen-covered, herbaceous-covered, and bare plots were 11, 8, and 3 inches, respectively. The aspen, by virtue of a root system several feet deeper than the herbaceous cover, consumed about 3 inches more water. The difference of 5 inches of available water in favor of bare soil over herbaceous cover is of interest. From a wateryield standpoint, however, the important question is not whether bare watersheds will yield most water but rather what kind of plant cover provides the greatest yield and still controls erosion.

Needed are studies under conditions of limited moisture--prevalent during the greater part of the year in Region I--to determine quantitatively the difference in available soil moisture depletion under sagebrush cover, native grass cover, and the several grass species adapted for reseeding. Also needed are studies to evaluate the differences in evapo-transpirational losses in terms of streamflow quality, additional quantity, and alterations in timing. Areas of greatest importance in this connection are as follows;

Runoff zone	Columbia Basin		Missouri Basin	
	Range type	Soil type P	Range type	Soil type
Subhumid			Sagebrush-grass	Soft sediments terrace

(c) What are the effects of water spreading over deep soils on the timing of streamflow.

Tributary streams flowing from the mountains into the larger valleys of the upper Missouri Basin often traverse several miles of deep alluvial outwash and terrace soils before reaching the main valley stream channel.

This condition provides opportunity on some of the smaller streams to divert water from the channel and spread it into these deep deposits of coarse material. In this way some of the high-stage spring streamflow may be stored underground for slower return to the stream channel as seepage flow later in the season. Several water-spreading operations already exist on small streams in the upper Basin. On none of them, however, has the effect of spreading on summer season streamflow been quantitatively evaluated. Studies are needed to determine how much water can be disposed of by spreading, the cover conditions required to accomplish spreading safely, and the effects on timing of downstream flow. Areas offering best opportunity for improving water yields by spreading are as follows:

Runoff zone	Columbia Basin		Missouri Basin	
	Range type	Soil type	Range type	Soil type
Subhumid			sagebrush-grass	alluvial outwash terrace

The foregoing analysis has pointed out the main objectives of watershed management in the different parts of the Region. It has presented a discussion of problems that appear to be obstacles to attainment of these objectives and indicated the kinds of answers needed for their solution. It has shown that, although problems of restoring satisfactory plant cover and soil conditions and of improving water yields are important in some parts of the Region, the problems of maintaining satisfactory forest and range conditions under continued use are, without doubt, the most important ones on a Region-wide scale. To bring the relative importance of these problems into clearer perspective, problem area priorities for each of the three main types of watershed management problems are summarized as follows based on urgency for solution.

Watershed Problem Area Priorities in Region I.

Watershed problem area	Type of Watershed Management Problem		
	Maintenance	Restoration	Improvement
white pine	A_1	B	
lodgepole pine	B	C	A_1
subalpine range	A_3	A_1	A_2
sagebrush-bunch-grass	C	A_2	B
larch	A_2	B	
Spruce-fir	B	B	A_3
low shrub-short-grass	C	A_3	
cottonwood-willow alder			B
Douglas-fir	B	C	B
ponderosa pine	C	C	
cedar-hemlock	C	C	
stream channels		C	

Watershed Problem Area Priorities in Region I.

RESEARCH NEEDS

It is quite obvious that the northern Region is faced with a large backlog of watershed management problems for which answers are required. The problem statements in the previous section indicate the source of answers needed. They indicate that solution for some problems lies in more rigorous application of measures already known to be effective, that answers for other problems can be found through more careful examination and appraisal of the effects of past practices, and that still other answers can be obtained only by research. Assistance in development and evaluation of methods and guides which have immediate practical application for maintaining protective watershed conditions appears to be one of Research's first responsibilities. Beyond this, however, Research also has responsibility for development of fundamental plant-soil-water relationships and evaluation of management impacts upon them. The following section outlines the specific objectives and scope of studies needed to develop the management guides and basic relationships necessary for problem solutions.

1. Watershed Maintenance Studies on Forest Land

   a. Sediment production effects of logging road system layout.

      (1) Physical effects of road layout on sediment production.

      Objective: Determine changes in amount of sediment created by carefully constructed jammer and tractor road systems and compare these changes with those from an access road suitable for Skyline Crane logging and from an undisturbed area.

      Scope: Construct sediment basins on four undisturbed watersheds. After a relatively short calibration period to determine sediment production from each, construct a single climbing access road and system of jammer contour roads on one, construct an access road and system of climbing tractor roads on another, and construct a single access road suitable for Skyline operation on a third. Continue measurements of sediment production for comparison with those before road construction. This study should be made in cooperation with NFA.

(2) Economic effects of road layout on sediment productien

Objective: To determine the ratio of differences in road building costs to differences in sediment production from jammer, tractor, and Skyline Crane logging road layouts.

Scope: Careful costs of road location and construction will be kept during the physical effects study outlined above. Care must be taken to insure that comparable timber harvest jobs are possible from each road system. Comparison of the differences in road costs with those of sediment production on the three treated watersheds should indicate whether or not sediment reduction can be obtained at a savings advantage or at a cost disadvantage by one system of road layout over the other.

Studies la(1) and la(2) are needed most urgently on glacial and granitic soils in white pine, larch, and spruce forests.

b. Erosion prevention measures on roads and skid trails

(1) Structural requirements for dispersion of surface runoff.

Objective: To determine proper spacing of drainage dips for diverting water from road surfaces and skid trails in order to prevent erosion-producing amounts of surface runoff from building up.

Scope: Development of guides to proper drainage spacing on soils of different degrees of erodibility can most quickly be accomplished by demonstration trials on going timber sales. A substantial basis for their development already exists in the drainage structure that have been installed on past sale areas. Initially, examination of the effectiveness of these structures and the conditions under which they have and have not been efefective in preventing rill erosion from getting started will be made. Such examinations will be required from several sale areas in each soil type. Detailed records of each structure's operation will be taken. Where such examinations do not provide sufficient information to establish spacing requirements, trial spacings will be installed on current sale areas and similar records kept. These examinations and records are a responsibility of Administration. Research's responsibility is the establishment of standards for making such examinations and analyses of records to develop requirements.

Study 1b(1) is most needed on glacial silt, granitic and loessal soils in white pine, larch, and spruce forest.

c. Effects of timber cutting on streamflow peaks and sediment production.

(1) Interception effect on precipitation

Objective: Determine differences in amount of snow and rainfall reaching ground in relation to depth and density of forest canopy.

Scope: Using plots in timber stands of different height and density, measure snow accumulation and rainfall. Develop relationships of stand density and volume to gross interception losses. (Some unanalyzed data on this are available from previous exploratory snow studies in white pine forest at Priest River Experimental Forest.

(2) Evaporation and melting effects on snow accumulation

Objective: Determine evaporational losses and melting from under-canopy and open-area snowpack on different exposures in relation to timber height and density.

Scope: There are two approaches to the problem of segregating evaporation and melting from the snowpack:

(a) Using plots of study 1c(1), install small transparent plastic lysimeters in the snowpack. Measure weight of snowpack in lysimeters at intervals and also weight of snowmelt water collected. From this compute difference, if any, which is evaporation. Develop relationships of amounts evaporated and melted to timber heights, densities, and exposure or aspect.

(b) Develop better methods of computing evaporation and melting from hydro-meteorological data such' as measurements of radiant heat energy, snow albedo, snow-surface temperature, dew-point temperature, air temperature, wind, and turbulent diffusion, all of which have an influence on these two processes. Development of such relationships will require a number of fundamental studies on the physics of snowmelt and evaporation for which special forest meteorological talents are needed to assist in design and evaluation.

(3) Snowmelt and transpiration effects on soil moisture recharge and depletion

Objective: Determine effects of snowmelt amount and rate on rate and time of soil moisture recharge and of transpiration on soil moisture depletion under different conditions of exposure and timber stand height and density.

Scope: On plots in stands of different height and density, in openings of different size, and on varying exposures in relation to solar insolation supplement measurements in studies 1c(1) and

1c(2) with measurements of moisture in soil mantle during period from beginning of snowmelt to just after time of snow disappearance and again during low stage of soil-moisture depletion in fall. This should indicate relative time at which water becomes available for streamflow on each exposure and cover condition and the relative amounts needed for soil moisture recharge before it becomes available.

(4) Cutting effects on snow accumulation, evaporation and melting, and soil moisture.

Objective: Determine changes in amount of snow accumulation and evaporational loss and in rate of snowmelt and soil moisture recharge and depletion caused by timber cutting.

Scope: Using plots on different exposures, employ results from studies 1c(1) through 1c(3) to crests, by timber cutting, the following kinds of conditions:

(a) On early melting exposures--timber stand condition giving combination of accumulation, evaporational loss, and melting that produces earliest recharge of soil moisture.

(b) On late melting exposures--timber stand condition giving combination of accumulation, evaporational loss, and melting that produces latest recharge of soil mantle.

Compare rate and time of recharge and depletion of soil moisture after timber cutting with that before to determine whether advance or delay in availabilty of water for streamflow is significant or not.

(5) Cutting effects on amount and timing of streamflow

Objective: Determine changes in streamflow peaks, shift in time of peak, and changes in sediment production produced by timber cutting.

Scope: After suitable period of streamflow and sediment calibration on undisturbed small watersheds, treat by cutting timber in accordance with results from studies 1c(1) through 1c(4) so that following conditions are represented on individual watersheds:

(a) No change from undisturbed

(b) Timber cut to create earliest snowmelt and recharge of soil moisture on normally early melting sites.

(c) Timber cut to create latest snowmelt and recharge of soil moisture on normally late melting sites.

(d) Timber cut to combine both b and c on same watershed.

Test effects of timber cutting on peak flow and sediment by comparing these characteristics for extended period after cutting with those before treatment and with those from uncut watersheds.

Studies 1c(1) through 1c(5) are needed most urgently in the humid zone in white pine forest, next in larch forest, and third in spruce-fir forest.

d. Effects of controlled burning and of dozer piling of slash on peak, timing, and quality of streamflow.

(1) Burning effects on infiltration capacity

Objective; Determine runoff and erosion by storm, season, and year following single and double burning for slash removal.

Scope: Using plots, measure surface runoff and sediment from singly and doubly burned slashed areas and compare measurements with those from unburned slashed areas on slopes of various steepness.

(2) Burning effects on soil storage capacity.

Objective: Determine effects of burning on bulk-density of soil mantle.

Scope: On plots of study 1d(1) measure bulk density of soil mantle before and after burning.

(3) Dozer piling effects on infiltration capacity

Objective: Determine runoff and erosion by storm, season, and year following dozer piling of slash.

Scope: Using plots, measure surface runoff and sediment from dozed areas subjected to different degrees of slash removal and compare measurements with those from undozed areas.

(4) Dozer piling effects on storage capacity

Objective: Determine effects of dozer piling on bulk-density of soil mantle.

Scope: On plots of study 1d(3) measure bulk-density of soil mantle before and after dozing operation.

(5) Burning and dozer piling effects on peak and time of streamflow, and on sediment production.

Objective: To determine effects of controlled burning and dozer piling of slash on peak flow, time of flow, and sediment production.

Scope: On small watersheds calibrated for streamflow and sediment apply treatments so that each is represented on individual watersheds:

(a) No treatment

(b) Cut and log timber, leave slash untouched

(c) Cut and log timber, broadcast burn slash

(d) Cut and log timber, pile, and leave

(e) Cut and log timber, pile, and burn

Continue measurements and develop streamflow and sediment relationships between watersheds for comparison with pretreatment relationships.

Studies 1d(1) through 1d(5) aremost important on loessal, glacial silt, and granitic soils in white pine, larch, and spruce forest and on dolomitic soils in lodgepole pine forest.

2. Watershed Maintenance Studies on Range Lands

a. Plant cover and soil requirements for control of summer storm runoff and erosion.

(1) Plant cover effects on surface runoff and erosion.

Objective: Determine plant and litter ground cover conditions needed to hold summer storm runoff and erosion to a minimum.

Scope: Using ungrazed infiltrometer plots representing a wide range in ground cover conditions, measure surface runoff and erosion from applied rainfall comparable in intensity and duration to those of major summer storms. Develop relationships between resulting amounts of runoff and erosion and amounts and distribution of ground cover and size of bare soil openings.

(2) Soil mantle effects on surface runoff and erosion.

Objective: Determine effects of soil bulk-density differences in surface layers of soil mantle on surface runoff and erosion.

Scope: On plots of study 2a(1) measure bulk-density of surface layers of soil mantle. Develop relation of bulk-density to surface runoff and ground cover condition.

Studies 2a(1) and 2a(2) are needed first on subalpine-grass-forb range, second on sagebrush-bunchgrass range, and third on low shrub-shortgrass range.

b. Grazing and trampling limits for maintenance of storm runoff and erosion control conditions on satisfactory range.

(1) Effects of trampling degree on ground cover and soil.

Objective: Determine degree of trampling that can be safely sustained by range without deterioration of plant cover and soil from protective conditions.

Scope: Using plots having ground cover conditions equal to or better than minimum requirements found from study

2a(1) to be needed for runoff and erosion control, manually inflict trampling of different intensities on plots and measure changes in density of ground cover, size of bare soil openings and bulk-density of soil. Repeat measurements annually to develop time regressions showing trend in these cover and soil characteristics under each degree of trampling.

(2) Effects of herbage production on ground cover

Objective: Determine amounts of plant herbage that need to be retained for ground cover increment to maintain minimum cover conditions required for runoff and erosion control.

Scope: Using plots replicating those of study 2b(1), simulate different degrees of herbage removal by clipping, including no removal and complete removal. Measure total herbage produced, herbage taken, ground cover density, and size of bare openings. Repeat clipping and measurements annually to develop time regressions showing trend in these cover characteristics under each degree of herbage removal.

(3) Relation of herbage removal and trampling disturbance to grazing intensity

Objective: Determine amounts of herbage removal and trampling disturbance created by different intensities of actual grazing use.

Scope: On key range sites having satisfactory cover and soil conditions for runoff and erosion control, subject small plots, equipped with hurdle fences, to different intensities of grazing use. In the case of cattle, intensity to be controlled by installing or removing hurdle fences at designated intervals to expose them to different animal unit months of use. In the case of sheep, control to be achieved by regulating frequency of once-over lightly use. Measure herbage taken and percent of area disturbed by trampling. Repeat measurements annually after grazing was to develop regressions showing amount of herbage removal and trampling disturbance in terms of animal unit months or frequency of grazing use.

(4) Relation of grazing intensity to ground cover and soil conditions required for runoff and erosion control.

Objective: Determine the limits of safe grazing use necessary to maintain protective ground cover and soil conditions.

Scope: On plots of study 2b(3) measure ground cover density, size of bare openings, and soil bulk-density annually after grazing use. Develop time regressions of ground cover density, size of openings, and bulk-density showing their trend for each intensity of grazing use. Limits of safe grazing use provided by the greatest intensity which, in terms of trampling and herbage removal effects, provides no decrease in ground cover density, no increase in size of bare openings, and no increase in soil bulk-density.

(5) Grazing use effects on streamflow peak and gross sediment production.

Objective; Evaluate effectiveness of criteria developed from studies 2a(1) through 2b(4) for controlling summer storm peak discharge and sediment production.

Scope: After a streamflow and sediment calibration period on small range watersheds having protective plant cover and soil conditions, subject them to the following grazing treatments:

(a) No Grazing.

(b) Stocking rate based on criteria developed from studies 2a(1) through 2b(4).

(c) Stocking rate in excess of that based on those studies.

Measure herbage removal, trampling disturbance, ground cover density, size of bare openings, and soil bulk-density periodically on sample plots or transects to determine range condition and trend. Measure streamflow and sediment to determine changes with time. Compare trend in watershed condition with changes in streamflow characteristics and sediment from each treatment.

Studies 2b(1) through 2b(5) are needed first on subalpine-grass-forb range, second on sagebrush-bunchgrass range, and third on low shrub-shortgrass range.

3. Watershed Restoration Studies on Forest Land

a. Vegetational measures for soil stabilization on road cuts and fills.

(1) Litter cover required to stop soil movement on road cuts and fills.

Objective: Determine effects of different amounts of mulch and methods of retention on steep cut and fill slopes to prevent soil movement.

Scope: Apply mulch of straw and of wood chips to small plots with sediment troughs on road cuts and fills. Compare soil movement from these plots with that from similarly equipped unmulched plots to evaluate durability of mulch and effectiveness for stopping soilmovement.

(2) Plant cover required to stabilize soil on road cuts and fills.

Objective: Determine kind of plant cover, method of establishment, and amount of cover needed to provide soil stability on road cuts and fills.

Scope: Test adaptability of suitable grass and indigenous tree species for establishment on small plots equipped with sediment troughs on deep cuts and long fill slopes. Compare establishment on mulched and unmulched and on fertilized and unfertilized plots. Compare soil losses from plots to evaluate effectiveness for control of soil movement.

Studies 3a(1) and 3a(2) are most needed on glacial silt, granitic, and loessal soils in white pine, larch, and spruce forest.

b. Peak streamflow and sediment effects from restoring timber on old burn brushfields.

(1) Interception effects on precipitation

Objective: Determine differences in amount of precipitation, especially snow, reaching ground in heavy brush stands and in dense timber stands of different height.

Scope: Using plots and recording raingages measure snow and rainfall in timber and brush stands and determine differences.

(2) Evaporation and melting effects on snow accumulation

Objective: Determine evaporational losses and melting from snowpack under timber stands, on brushfields, and in open areas in relation to northerly and southerly exposures.

Scope: Using plots of study 3b(1) install small transparent plastic lysimeters in the snowpack. Measure weight of snow in lysimeters at intervals and also weight of snowmelt water collected. From this compute difference, if any, which is evaporation. Compare amounts evaporated and melted under each timber stand height and density with amounts from brushfield sites and open areas. Additional studies are also needed to related amounts evaporated and melted to the hydrometeorological factors causing them, such as radiant energy, albedo, temperature, wind, and turbulent diffusion, so that these causative factors may be measured and used to make accurate estimates of evaporation and melting. Meteorological assistance will be required to satisfactorily handle such studies.

(3) Snowmelt and transpiration effect on soil moisture recharge and depletion.

Objective: Determine effects of amount and rate of snowmelt on rate and time of soil moisture recharge and of transpiration on soil moisture depletion for each exposure under timber and brush cover conditions.

Scope: On plots of studies 3b(1) and 3b(2) measure soil moisture in soil mantle during period from beginning of snowmelt to just after snow disappearance and again during low stage of soil moisture depletion in fall. This should indicate relative time at which water becomes available for streamflow on each exposure and cover condition and the relative amounts needed for soil mantle recharge before it becomes available.

(4) Timber planting effects on amount and timing of streamflow.

Objective: Determine changes in streamflow peaks, shift in time of peak, and changes in sediment produced by timber establishment in old burn brushfields.

Scope: After a suitable period of streamflow and sediment calibration on small brush-covered watersheds, treat by timber planting to obtain following conditions on individual watersheds:

(a) Retain brush over entire watershed

(b) Retain brush on exposures which provide water available for streamflow latest.

(c) Plant timber over entire watershed.

Using plots in these watersheds previously calibrated for soil moisture recharge and depletion under brush cover, compare rate and time of recharge during growth of planted timber stands with those before to evaluate significance of any effects on time water becomes available for streamflow. Test effects of timber planting throughout period of establishment to merchantable size on peak flow and sediment by comparing streamflow and sediment characteristics of planted watersheds with those before planting and with those from the brush-covered watersheds.

Studies 3b(1) through 3b(4) are needed most in the humid zone in white pine forest and especially in the large brushfield areas of the St. Joe and Clearwater Forests.

4. Watershed Restoration Studies on Range Lands

   a. Cover restoration measures for controlling runoff and stabilizing soil on critically eroding range land.

      (1) Species adaptability for survival on adverse sites.

      Objective: Determine range grass, forb, and browse species best able to survive, grow, and reproduce on severly eroded sites.

      Scope: Using small plots, transplant vigorous mature plants from good sites and evaluate survival, growth, and seed-production ability of each. Select most promising for further seeding tests.

      (2) Species adaptability for seedling establishment.

      Objective: Determine which species, if any, are capable of establishment beyond seedling stage without treatment other than seedbed preparation.

      Scope: On small plots, reseed most promising possibilities from study 4a(1) using several different methods of seedbed preparation.

(3) Moisture-conserving effects on seedling establishment

Objective: Determine effects of treatment to conserve moisture and reduce insolation on establishment and survival.

Scope: Using plots, apply contour trenching treatment to catch all runoff and mulching to reduce insolation and evaporation. Reseed most promising species from studies 4a(1) with best planting methods from study 4a(2). Measure soil moisture recession and root development and correlate with survival. Compare with similar measurements from untrenched and unmulched plots.

(4) Fertilizer effects on seedling establishment and growth.

Objective: Determine nutrient deficiencies in soils on severly eroded sites and evaluate effects of fertilizers to eliminate them on establishment and growth of reseeded plant cover.

Scope: Sample soils on adverse sites and have chemical analyses made to determine what fertility deficiency, if any, exists. On plots, extend study 4a(3) to include several levels of fertilizing treatment. Compare survival and growth of seedlings with that from unfertilized plots.

(5) Reseeded plant cover effects on storm runoff and erosion.

Objective: To evaluate the effectiveness of any successfully established cover resulting from studies 4a(1) through 4a(4) for controlling storm runoff and stabilizing soil on adverse sites.

Scope: Develop mature stands of reseeded cover on several adverse sites. Using infiltrometer plots apply simulated high-intensity rainfall and measure resulting amounts of runoff and erosion. Compare ground cover conditions with those required for effective control as determined from study 2a(1). Compare amounts of runoff and erosion with those obtained under effective control in study 2a(1).

Studies 4a(1) through 4a(5) are most needed on extensive areas of critically eroded subalpine range, next on more localized areas of badly depleted cover on sagebrush-bunchgrass range where elk winter, and thirdly on rapidly eroding low shrub-shortgrass range.

b. Grazing and trampling limits for restoration of storm runoff and erosion control conditions on unsatisfactory range.

(1) Effects of trampling degree on ground cover and soil.

Objective: Determine amount of change in ground cover density, size of bare openings and soil bulk-density caused by different intensities of trampling on range with unsatisfactory cover conditions.

Scope: On key range sites having unsatisfactory cover and soil conditions for storm runoff and erosion control as determined from studies 2a(1) and 2a(2), manually inflict trampling of different degrees on plots and measure changes in ground cover density, size of bare openings, and soil bulk density. Repeat measurements annually to develop time regressions showing trend in these cover and soil characteristics under each degree of trampling.

(2) Effects of herbage production on ground cover

Objective: Determine amounts of plant herbage that need to be retained for ground cover increment to provide upward trend in amount of ground cover.

Scope: Using plots replicating those of study Ab(1), simulate different degrees of herbage removal by clipping, including no removal and complete removal. Measure total herbage produced, herbage taken, ground cover density, and size of bare openings. Repeat clipping and measurements annually to develop time regressions showing trend in these cover characteristics under each degree of herbage removal.

(3) Relation of herbage removal and trampling disturbance to grazing intensity.

Objective: Determine amounts of herbage removal and trampling disturbance created by different intensities of actual grazing use.

Scope: On key range sites having unsatisfactory cover and soil conditions for runoff and erosion control, subject small plots, equipped with hurdle fences, to different intensities of grazing use. In the case of cattle, intensity to be controlled by installing or removing hurdle fences at designated intervals to expose them to different animal unit months of use. In the case of sheep, control to be achieved by regulating frequency of once-over-lightly use. Measure herbage taken and percent of area disturbed by trampling. Repeat measurements annually after grazing use to develop regressions showing amount of herbage removal and trampling disturbance in terms of animal unit months or frequency of grazing use.

(4) Relation of grazing intensity to trend in ground cover and soil conditions.

Objective: Determine limits of safe grazing use necessary to provide upward trend in ground cover and soil conditions.

Scope: On plots of study 4b(3) measure ground cover density, size of bare openings, and soil bulk-density

(5) Grazing use effects on streamflow peak and gross sediment production.

Objective: Determine effectiveness of criteria developed from studies 4b(1) through 4b(4) for controlling summer storm peak discharge and sediment production.

Scope: After a streamflow and sediment calibration period of sufficient length to include a number of summer rainstorms, subject small range watersheds having unsatisfactory cover and soil conditions to the following grazing treatments.

(a) No grazing

(b) Stocking rate based on criteria developed from studies 4b(1) through 4b(4).

(c) Stocking rate in excess of that based on those studies.

Measure herbage removal, trampling disturbance, ground cover density, size of bare openings, and soil bulk-density periodically on sample plots or transects to determine range condition and trend. Measure streamflow and sediment to determine changes with time. Compare trend in watershed condition with changes in streamflow characteristics and sediment from each treatment.

Studies 4b(1) through 4b(5) are needed first on subalpine-grass-forb range, second on sagebrush-bunchgrass range, and third on low shrub-shortgrass range.

5. Watershed Improvement Studies on Forest Lands

a. Effects of timber cutting on streamflow amount, peak, and timing and on sediment production.

(1) Interception effects on precipitation.

Objective: Determine differences in amount of snow and rainfall reaching ground in relation to height and density of forest canopy and size of openings in timber stands.

Scope: Using plots in timber stands of different height and density and in different sizes of openings in the timber, measure snow accumulation and rainfall. Develop relation of timber height, density, and size of openings to gross interception losses.

(2) Evaporation and melting effects on snow accumulation.

Objective: Determine evaporational losses and melting from under-canopy and open-area snowpack on different exposures in relation to timber height and density.

Scope: Using small plastic lysimeters on plots of study 5a(1) measure weight of snowpack in lysimeters at intervals and also weight of collected snowmelt water from lysimeters. From this compute difference which is evaporation. Develop relationships of amounts evaporated and melted to timber height, density, size of openings, and exposure or aspect. Complete investigation requires a number of studies to better develop ways of relating measurable hydro-meteorological elements that affect evaporation and melting to the amounts involved. Needed for this is the assistance of trained forest meteorologists to assist in design, instrumentation, and evaluation of studies.

(3) Snowmelt and transpiration effects on soil moisture recharge and depletion.

Objective: Determine effects of snowmelt amount and rate on rate and time of soil moisture recharge and of transpiration on soil moisture depletion under different conditions of exposure and timber height and density.

Scope: On plots in stands of different height and density, in openings of different size and on varying exposures supplement measurements of study 5a(1) and 5a(2) with measurements of moisture in soil mantle during period from beginning of snowmelt to after disappearance of snow and again during low stage of soil-moisture depletion in the fall. This should provide measure of probable magnitude of changes in amount of water available for streamflow and possible shift in time this water becomes available as a result of creating different stand conditions by management.

(4) Cutting effects on snow accumulation, evaporation and melting, and soil moisture.

Objective: Determine changes in amount of snow accumulation and evaporation and in rate of snowmelt and soil moisture recharge and depletion caused by timber cutting.

Scope: Using plots on different exposures, employ results of studies 5a(1) through 5a(3) to create, by timber cutting, the stand conditions of density, height, and size of openings giving the combination of accumulation, evaporation, and melting that produces latest recharge of the soil mantle on each exposure. Compare rate and time of recharge and depletion of soil moisture after timber cutting with that before to determine whether delay in availability of water for streamflow is significant or not.

(5) Cutting effects on amount and timing of streamflow

Objective: Determine changes in streamflow amount, peak, and time of peak, and changes in sediment production produced by timber cutting.

Scope: After suitable period of streamflow and sediment calibration on undisturbed small watersheds, treat by cutting timber in accordance with results from studies 5a(1) through

5a(4) so that following conditions are represented on individual watersheds:

(a) No change from undisturbed

(b) Timber cut to create latest snowmelt and recharge of soil moisture on all exposures.

Test effects of timber cutting on peak flow, amount, and timing of streamflow and on sediment by comparing these characteristics for extended period after cutting with those before treatment and with those from uncut watersheds.

Studies 5a(1) through 5a(5) are needed most in the humid zone in lodgepole pine forest, next in spruce-fir forest, and third in Douglas-fir forest.

b. Effects of riparian cover removal on amount and timing of streamflow and on sediment production.

(1) Effects of cutting vegetation in streamside zone

Objective: Determine changes in amount and time of flow caused by cutting vegetation having root systems within the permanent water table zone.

Scope: On small watersheds obtain continuous measurements of streamflow and measure sediment for a suitable calibration period. Treat watersheds so that following treatments are represented on individual drainages:

(a) No cover removed

(b) All timber in streamside zone removed

(c) All vegetation in streamside zone removed.

Continue measurements of streamflow and sediment for extended period following cutting. Compare with pre-cutting measurements and with measurements from untreated watershed.

Study 56(1) is of most importance in spruce-fir, lodgepole pine, and Douglas-fir forest and alder-willow-cottonwood cover in deep valley-fills of upper Missouri River tributaries.

6. Watershed Improvement Studies on Range Lands.

a. Effects of snowdrifting on timing of streamflow.

(1) Terrain effects on natural drifting and depletion.

Objective: Determine kinds of sites where snow accumulation from drifting is greatest and snow remains on the ground longest.

Scope: Using aerial photographs taken weekly from beginning of melting to disappearance of snow, develop overlay maps showing location of longest remaining snow fields in several watersheds on subalpine range. After first year establish snowmeasuring courses or points to determine differences in maximum accumulation on these natural drift areas and normal undrifted accumulation on surrounding areas. Continue measurements for several years. Relate amount of drift accumulation and time of depletion to exposure, slope, and wind direction.

(2) Drifting efficiency of various structures.

Objective: Determine effects of difference kinds of barriers for drifting of snow.

Scope: Cooperate with Montana State University in wind-tunnel tests of different style and size of fences and types of planted windrows for drifting, using borax or other suitable material in lieu of snow. Install most effective barriers on several test sites in watersheds of study 7a(1) and measure differences in accumulation before and after installation. Also compare differences in drift accumulation on previously undrifted areas with added drift accumulation caused by installation on natural drift areas.

(3) Techniques for retarding snowmelt.

Objective: Determine effects on snowfield melt rates of surface materials for insulation.

Scope: Using small plastic lysimeters installed in the snowfield pack compare rate of snowmelt from untreated condition with that from different materials and thicknesses of insulation to retard melt. Apply treatments found to be most effective in retarding melting to control areas on snowfields and further determine effectiveness by measuring vertical ablation rates. Evaluate significance of effects for delaying time of snowmelt.

(4) Drifting and snowmelt delay effects on timing of streamflow.

Objective: Determine effect on streamflow peak and timing caused by induced drifting and treatment to retard melting of snow.

Scope: Calibrate streamflow from small watersheds having natural drift areas and providing opportunity for erecting drifting structures. Treat watersheds so that following conditions are represented on individual drainages:

(a) No treatment

(b) Erect drift structures only

(c) Erect structures and apply melt retardation treatment at beginning of melting season.

Continue streamflow measurements. Develop pretreatment relation of discharges before treatment. Compare predicted streamflow with that actually obtained to evaluate effects of treatments on peak stage and time of flow.

Studies 6a(1) through 6a(4) are needed on subalpine-grass-forb range in the upper Missouri Basin.

b. Effects of converting brush cover to grassland on streamflow

(1) Evapo-transpiration effects on soil moisture.

Objective: Determine evapo-transpiration effects on extent and rate of soil moisture depletion under brush, native grass, and several species useful for reseeding.

Scope: Using large plots, obtain periodic measurements of soil moisture throughout the soil mantle throughout the year. Determine and compare amount of mantle depletion during growing season, and time of recharge in spring.

(2) Soil moisture depletion effects on streamflow

Objective: Determine effects of soil moisture depletion under brush, native grasses, and reseeded species on amount of streamflow.

Scope: On small watersheds covered with brush and previously calibrated for streamflow over suitable period, apply treatments so that each is represented on individual watersheds.

(a) Retain brush cover intact

(b) Remove brush cover and allow native grasses to remain.

(c) Remove brush cover and reseed with species showing least depletion of soil moisture.

Continue streamflow measurements for extended period and compare streamflow with predicted amounts from pretreatment calibration relationships.

Studies 6b(1) and 6b(2) are needed primarily on sagebrush bunchgrass range. Similar studies involving effects of different species for reseeding subalpine range are also needed.

c. Effects of water-spreading on time of streamflow.

(1) Absorptive capacity of spreading-ground soil material.

Objective: Determine ability of soil to infiltrate water during high streamflow stages.

Scope: Using large plots on gently sloping alluvial outwash soils, construct closely spaced ditches with frequently spaced cross baffles, at less than 1/2 percent grade across slope, crisscrossing back and forth. Determine linear feet and surface area of ditch absorbing surfaces. On comparable area construct ditch system of similar size and reseed with sod-forming grasses. When stand has developed, pump water at various known rates into each ditch system during high flow states of spring runoff. Begin with small amounts and repeat process, increasing the amounts, until water begins to pend above outlets on baffles. Compare rates of application at this point on sodded and unsodded ditches.

(2) Spreading effects on streamflow

Objective: Determine effects of spreading on stage and timing of streamflow.

Scope: On a small stream with an alluvial outwash plain extending from the point where it emerges from mountains, install two streamgaging stations. One of these located above diversion for spreading, one some distance belpw spreading grounds. Calibrate both stations for streamflow and develop relation between them. Construct water-spreading ditch system over alluvial plain and divert water into it. Continue measurements of streamflow and compare stage and time of flow at lower station with predicted amounts from upper station.

7. Other Kinds of Studies Needed on Physical and Physiological Processes

a. Physical processes

(1) Characteristics of summer rainstorms.

(Needed for this is a network of 10 c.m. radar stations, perhaps every 10,000 square miles (55), similar to the 39 recently authorized for installation by the U. S. Weather Bureau).

(2) Amount and rate of soil water movement.

(3) Hydraulics of underground and surface flow of water.

(4) Develop methods of measuring the inherent erodibility of soils and factors that affect it.

(5) Develop methods of measuring and evaluating effects of wind, temperature, vapor pressure, turbulent diffusion, and radiation on evaporation and snowmelting and how vegetation alters these effects.

(b) Physiological processes

(1) Factors affecting transpiration by plants and develop direct methods for determining water use by vegetation.

PROPOSED PROGRAM OF WATERSHED MANAGEMENT RESEARCH

1. Minimum Desirable Program

The foregoing analysis of watershed management problems in the Northern Region has shown quite clearly that, depending upon management objectives in relation to needs, the following problem areas are of outstanding importance:

Kind of problem	Management objectives	Problem area			
		Cover	Soil	Drainage	Priority
Maintenance	prevent increases in snowmelt runoff peaks and in sediment	white pine	loess	Columbia	1
		larch	glacial	Columbia	2
		subalpine range	dolomitic	Missouri	3
Restoration	reduce summer storm runoff peaks and sediment	subalpine range	dolomitic	Missouri	1
		sagebrush-grass	soft sediments	Missouri	2
		low shrub-shortgrass	hard sediments	Missouri	3
Improvement	increase summer streamflow without increasing summer storm or snowmelt runoff peaks and sediment	lodgepole pine	dolomitic	Missouri	1
		subalpine range	dolomitic	Missouri	2
		spruce-fir	dolomitic	Missouri	3

This analysis has also outlined the specific objectives and scope of research or other action needed to provide solutions for these problems. Recapitulation of the studies required to provide problem solutions for only the first-priority areas indicated above shows the immediate investigative needs from which a practicable research program must be selected.

a. Watershed Maintenance Studies in White Pine Forest

- (1) Plot studies
  - (a) Short-term (less than 5 years)
    - (1) Structural requirements for surface runoff dispersion on roads and skid trails - lb(l)[1]
    - (2) Interception effects on precipitation - lc(l)
    - (3) Burning effects on infiltration capacity - ld(l)
    - (4) Burning effects on soil storage capacity - ld(2)
    - (5) Dozer piling effects on infiltration capacity - ld(3)
    - (6) Dozer piling effectson soil storage capacity - ld(4)
  - (b) Medium-term (5 to 10 years)
    - (1) Evaporation and melting effects on snow accumulation - lc(2)
    - (2) Snowmelt and transpiration effects on soil moisture-lc(3)
  - (c) Long-term (more than 10 years)
    - (1) Cutting effects on snow accumulation, evaporation, melting, and soil moisture - lc(4)
- (2) Watershed studies
  - (a) Medium-term (5 to 10 years)
    - (1) Physical effects of road layout on sediment production-la(l)
    - (2) Economic effects of road layout on sediment production-la(2)
  - (b) Long-term (more than 10 years)
    - (1) Cutting effects on amount and timing of streamflow-lc(5)

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[1] Numbers at end of study titles refer to location of study prospectus in previous section on Research Needs.

        (2) Burning and dozer piling effects on peak and time of streamflow, and on sediment - 1d(5)

b. Watershed Restoration Studies on Subalpine Range

- (1) Plot studies
    - (a) Short-term (less than 5 years)
        - (1) Plant cover effects on surface runoff and erosion - 2a(1).
        - (2) Soil mantle effects on surface runoff and erosion - 2a(2).
        - (3) Species adaptability for survival on adverse sites - 4a(1).
        - (4) Moisture-conserving effects on seedling establishment - 4a(3).
        - (5) Fertilizer effects on seedling establishment and growth - 4a(4)
        - (6) Reseeded plant cover effects on storm runoff and erosion - 4a(5).
    - (b) Medium-term (5 to 10 years)
        - (1) Species adaptability for seedling establishment - 4a(2).
        - (2) Relation of herbage removal and trampling disturbance to grazing intensity - 4b(3)
    - (c) Long-term (More than 10 years)
        - (1) Effects of trampling degree on groundcover and soil - 4b(1).
        - (2) Effects of herbage production on ground cover -4b(2).

(3) Relation of grazing intensity to trend in ground cover and soil condition - 4b(4)

(2) Watershed studies

(a) Long-term (more than 10 years)

(1) Grazing use effects on streamflow peak and sediment production - 4b(5)

c. Watershed Improvement Studies in Lodgepole Pine Forest

(1) Plot studies

(a) Short-term (less than 5 years)

(1) Interception effects on precipitation - 5a(1)

(b) Medium-term (5 to 10 years)

(1) Evaporation and melting effects on snow accumulation - 5a(2)

(2) Snowmelt and transpiration effects on soil moisture - 5a(3)

(c) Long-term (more than 10 years)

(1) Cutting effects on snow accumulation, evaporation, melting, and soil moisture - 5a(4)

(2) Watershed studies

(a) Medium-term (5 to 10 years)

(1) Effects of cutting vegetation from riparian zone-5b(1)

(b) Long-term (more than 10 years)

(1) Cutting effects on amount and timing of streamflow - 5a(5)

Summarizing, this recapitulation shows that the research needed to provide effective management criteria for only the single most important problem in each of the three highest-priority problem areas in the Region involves at least 24 plot-type and 7 watershed-type investigations distributed as follows:

Type of Study	Probable time required	Problem area		
		White pine	Subalpine range	Lodgepole pine
Plot	short-term	6	6	1
	medium-term	2	2	2
	long-term	1	3	1
Watershed	medium-term	2		1
	long-term	2	1	1

It is estimated that, if each of these three problem projects were to be attacked simultaneously, it would involve an initial investment cost for research installations of about $200,000.00 and a net annual operating budget of about $200,000.00 over the next 20 to 25 years distributed between projects approximately as follows:

Cost item	Problem area		
	White pine	Subalpine range	Lodgepole pine
Facilities investment	$70,000	$60,000	$70,000
Annual operating	80,000	60,000	60,000

This program constitutes the minimum acceptable level to which research should be expanded if substantial progress is to be made towards surmounting the main obstacles to good watershed management in the Northern Region.

2. Feasible Program with Current Facilities

A research program that is susceptible of accomplishment depends largely upon the money and manpower available. The current annual allocation for watershed management research in the Northern Region territory is $17,000 including one man. Obviously these facilities are inadequate to undertake the above-outlined program of research. In fact, they will not support a full-scale attack in even one of the three priority problem areas. A feasible program of research must be somewhat more modest for the present.

Selection of a research program within current capabilities involves several considerations. The most profitable choice of problems for an immediate program depends upon relative urgency for solution and susceptibility to research attack. From standpoint of urgency for solution there appears to be little choice between the three high-priority problem areas. For different reasons each is of importance and requires research effort.

Considering susceptibility of problems to attack, there are some important differences between the three priority problem areas. The white pine problem area is most developed and, hence, most accessible for research purposes. The lodgepole pine area is rapidly becoming accessible with the increase in cutting operations there. Least accessible is the subalpine rangearea, virtually no roads penetrating into it. Because of deep snow, winter accessibility in any of the problem areas is difficult and practically impossible without an oversnow vehicle.

Possibilities for cooperative assistance from outside of the Station appear to be best in the lodgepole pine problem area. Here the U. S. Geological Survey has indicated interest in the effects of timber cutting on streamflow and groundwater characteristics and willingness to cooperate financially in a study program. Some arrangements are also possible for cooperative work on the subalpine range restoration problem with Agricultural Research Service who have already begun some work on species adaptability, methods of planting, and fertilizer studies. In the white pine problem area the best opportunity for cooperation exists with the Wildlife Research Unit at the University of Idaho on a watershed study of logging effects on streamflow peaks, sediment production, and trout habitat.

Opportunities for within-Station cooperative effort with other Divisions appear best with Forest Management Research and especially in the white pine problem area. Though much of the basic silviculture of white pine has been developed, studies in old growth stands are continuing at Deception Creek Experimental Forest and studies are proposed in areas of younger stands at Priest River Experimental Forest. Both of these areas, and especially Deception Creek, afford excellent possibilities for research because of areas available and existing plant facilities. Some opportunity will also be provided for cooperative work with Forest Management Research in the lodgepole pine problem area where silvicultural management studies are being planned. Disadvantage here in comparison to the white pine area is lack of a research plant from which to work. To what extent cooperative efforts can be achieved with Range Management Research on the high elevation range problem area is presently not clear. Though this is one of Range Research's high priority problem areas whether or not they can include work on it in their immediate program is uncertain.

In each of the three main problem areas of the Region interdependence of many studies will dictate the specific sequence or order in which research can be scheduled. For example, in the white pine and lodgepole areas plot studies to determine interception, evaporation, and snowmelt characteristics in different kinds of timber stands must logically precede studies to evaluate the way in which timber cutting alters these characteristics. Similarly, evaluation of cutting effects on soil water available for streamflow necessarily must precede investigation of effects on actual streamflow characteristics. On subalpine range, plot investigations to determine the effects of trampling and herbage removal on groundcover and soil conditions are necessary to provide the tools with which to evaluate the effects of grazing intensity on trend in cover and soil conditions. Thus, the priority of specific studies and, hence, of the research program in each problem area is fairly well fixed due to the sequential need for results from certain studies before others can be intelligently undertaken. In addition, the long-term studies needed involve, for the most part, watershed installations and servicing at costs substantially in excess of available funds. Efforts of an immediate program, therefore, must be largely of a short-term study nature which means, essentially, plot-type investigations.

There are two general kinds of watershed management information needed in the Northern Region. One of these is quick development of watershed protection criteria in connection with such activities as road building and logging. The other is development of quantitative relationships which express the hydrologic effects of management treatments on streamflow and soil stability characteristics of forest and range watersheds. Desirable is a balance between these two which provides some of the former but places emphasis on the latter.

These considerations lead one to the following conclusions:

1. Between the three high-priority problem areas there is little choice for initiating a research program based upon any difference in urgency for solution.
2. Based upon susceptibility to research attack the white pine problem area appears to offer the best opportunity and the subalpine range problems area the least.
3. Because of the investment required by watershed studies in equipment and manpower, a current study program will, of necessity, be almost entirely restricted to plot-type investigations.
4. For the greatest research returns in the long run, especially in laying a foundation for possible expanded research in the Northern Region, major study effort should be directed at quantitative evaluation of basic hydrologic processes.

Based upon these conclusions, the following actions are recommended to initiate a research program within existing capabilities:

1. In White Pine Forest
   a. Complete analysis of outstanding data on snow accumulation and melting under different forest conditions at Priest River Experimental Forest.
   b. Initiate the following plot studies at Deception Creek and Priest River Experimental Forests:
      (1) Interception effects on precipitation - 1c(1)
      (2) Evaporation and melting effects on snow accumulation - 1c(2)
      (3) Snowmelt and transpiration effects on soil moisture - 1c(3)
      (4) Timber cutting effects on snow accumulation, melting, and soil moisture characteristics - 1c(4)

c. Locate, and arrange for reserving in uncut condition, approximately 12 forested watersheds of from 200 to 400 acres in area for possible future conduct of studies on effects of timber cutting on streamflow peaks and sediment production - 1c(5).

2. In Lodgepole Pine Forest

   a. Initiate the following plot studies at suitable locations in mature lodgepole forest in the upper Missouri Basin:

      (1) Interception effects on precipitation - 5a(1)

      (2) Evaporation and melting effects on snow accumulation -5a(2).

      (3) Snowmelt and transpiration effects on soil moisture -52(3).

      (4) Timber cutting effects on snow accumulation, evaporation, melting, and soil moisture - 5a(4).

   b. Locate, and reserve in uncut condition approximately 9 forested watersheds of from 200 to 400 acres in area for possible future conduct of studies on effects of timber cutting on amount and timing of streamflow-5a(5), and on effects of riparian cover removal on water yields-5b(1).

3. On Subalpine Range

   Cooperate informally with Agricultural Research Service on artificial revegetation studies without entering into them on a work project basis.

4. Regionwide

Cooperate with and assist NPA in development of criteria for effective erosion control measures on roads and skid trails. This job involves three aspects:

a. Development of system for examining and reporting on effectiveness of measures employed on each timber sale area.

b. Evaluation of reports to develop guidelines for effective dispersal of water to prevent erosion.

c. Testing of recommended measures through application on new sale areas by NFA - 1b(1).

A proposed schedule for initiating the studies and other elements of this program is shown in the following table for an initial 5-year period. Sometime near the end of this initial 5-year period, the watershed problem priorities and research needs for the Region should again be considered so that desirable changes in emphasis or additional study projects which may become possible can be planned for the subsequent period.

Problem area	Study Activity	Year				
		1	2	3	4	5
White Pine Forest	1. Analysis of existing snow data	x				
	2. Location of experimental watersheds	x				
	3. Interception effects on precipitation	x	x	x	x	x
	4. Evaporation and melting effects on snow accumulation		x	x	x	x
	5. Snowmelt and transpiration effects on soil moisture			x	x	x
Lodgepole Pine Forest	1. Location of experimental watersheds	x				
	2. Interception effects on precipitation	x	x	x	x	x
	3. Evaporation and melting effects on snow accumulation		x	x	x	x
	4. Snowmelt and transpiration effects on soil moisture			x	x	x
Subalpine Range	1. Consultation and field trip with ARS on revegetation study areas	x	x	x	x	x
Regionwide	1. Develop system for collecting information on effectiveness of erosion control measures	x				
	2. Evaluation of reports and development of guides		x	x	x	
	3. Testing of guides by application on sale areas					x

It is obvious that, until facilities that are realistically correlated with research needs become available, the program that can be undertaken will not permit complete development and evaluation of the management principles and practices necessary to meet desired hydrologic objectives on Northern Region watershed lands. This immediate proposed program, however, should, if carried out, furnish some practical watershed protection guides and, more importantly, also provide the initial hydrologic foundation required for more intensive research as available facilities become more adequate.

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